# Public Health Assessment

**Initial/Public Comment Release**

## Evaluation of Exposures to Contaminants in Soil, Sediments, and Groundwater, Bremerton Gasworks Superfund Site Bremerton, Kitsap County, Washington

**FEBRUARY 26, 2014**

**COMMENT PERIOD ENDS: MARCH 28, 2014**

Prepared by

The Washington State Department of Health
Under Cooperative Agreement with the
Agency for Toxic Substance and Disease Registry

# Foreword

The Washington State Department of Health (DOH) prepared this Public Health Assessment under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services responsible for health issues related to hazardous substances.

This Public Health Assessment was prepared in accordance with ATSDR methodologies and guidelines. ATSDR reviewed this document and concurs with its findings based on the information presented. The findings are relevant to conditions at the site during the time this report was written. It should not be relied upon if site conditions or land use changes in the future. The glossary in Appendix A defines technical terms.

Use of trade names is for identification only and does not imply endorsement by DOH, the Centers for Disease Control and Prevention (CDC), ATSDR, the Public Health Service, or the U.S. Department of Health and Human Services.

For additional information, please contact us at 1-877-485-7316 or visit our web site at www.doh.wa.gov/consults.

For persons with disabilities this document is available on request in other formats. To submit a request, please call 1-800-525-0127 (TTY/TDD call 711).

For more information about ATSDR, contact the CDC Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's web site at www.atsdr.cdc.gov.

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# Summary

## *Introduction*

Past releases of polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, and metals from the Bremerton Gasworks Superfund site in Kitsap County, Washington have occurred. These releases resulted in contamination of soil, groundwater, and sediment along the shoreline of the Port Washington Narrows. The Bremerton Gasworks Superfund site centers around a former manufactured gas plant (MGP) that operated from 1930 to 1963. Other past and current industrial activities adjacent to the former MGP may have also contributed to contamination. These activities include but are not limited to fuel storage and distribution, marine salvage and repair, boat part and pier float fabrication, electroplating; sheet metal duct work, concrete fabrication, possible landfill activity, etc.

The U.S. Environmental Protection Agency (EPA) is developing plans for a remedial investigation (RI) and feasibility study (FS) for cleanup. Through this process, EPA will determine the site boundary by investigating all sources and extent of contamination. For this public health assessment, the term 'site' refers to upland, shoreline, and waterway areas near the former MGP. This includes nearby locations of current and past industrial activities that may have contributed to contamination.

## *Overview*

DOH reviewed the analytical results of soil, groundwater, and sediment samples taken from the site. There are four general areas of public health concern addressed in this document:

- Potential of exposure from touching or accidentally ingesting chemicals from contaminated site soils and shoreline sediments.
- Potential of drinking contaminated groundwater.
- Potential of exposure from eating berries grown on the site and eating fish or shellfish living near the site.
- Physically unsafe areas near the site.

DOH reached six conclusions in this public health assessment:

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**Conclusion 1.** Trespassing on the site could result in physical injury. This is an urgent public health hazard. Actions to remove or prevent these hazards have been recommended.

**Basis for Decision.** Several physical hazards are present at the site.

- The bluff at the end of Pennsylvania Avenue is very steep and has a well used path. This path leads to an area where a rope is necessary to go down to the shoreline. One of the owners, as well as Kitsap Public Health District, has cut this rope to discourage trespassers.
- At the bottom of the path, debris from former waste dumping is emerging from the bluff and shoreline sediment. Of concern is a rusted metal tank located adjacent to the path and

hidden by brush. A person could very easily fall in or on the tank and become seriously injured.
- Two large former ballast tanks are abandoned on the shoreline. These tanks are heavy, anchored to the shoreline with an old rope, and do not move. It is not known what was in these tanks. Access at low tide could result in injury if a person tried to climb these tanks. They may even become trapped if entry is achieved.

**Next Steps**. To protect residents, visitors, and trespassers, Washington State Department of Health (DOH) recommends the following:

- A sign be installed at the end of Pennsylvania Avenue prohibiting beach access.
- The rusted tank at the foot of the bluff be removed or fenced within three months.
- The submarine ballast tanks be removed by the owner in collaboration with EPA and Washington State Department of Natural Resources (DNR).

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**Conclusion 2.** Touching or accidentally ingesting sediments for more than a year could harm the health of children or adults.

**Basis for Decision.** PAHs were found in sediments near seeps and a former pipe that led to the beach. Playing at the beach, touching, or accidentally ingesting these sediments could result in an increased risk for developing cancer. The risk estimates exceed EPA's range of acceptable estimated cancer risk.[1] For residents, we estimate 5 additional cases of cancer will develop for every 1,000 people exposed over a lifetime. Visitors and trespassers also exceed the acceptable range of cancer risk. Further information is needed to know how widespread the contamination is along the shoreline.

**Next Steps.** To protect residents and visitors, DOH recommends the following:

- Ongoing source(s) of contaminants be identified and removed or mitigated to reduce the potential of exposure.
- People protect their health by not walking or playing on the shoreline near the site.
- Parents monitor their children's behavior while playing outdoors to prevent them from going onto the shoreline.
- EPA facilitates the maintenance of the capped area on the shoreline. The cap consists of an absorbent clay mat covered with large rocks. Maintenance is recommended to continue until the extent of contamination is known and a remedy is determined.
- Kitsap Public Health District facilitates replacement of signs on shoreline warning people of contamination.
- Site access be restricted until further characterization and health assessments are completed.

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**Conclusion 3.** DOH cannot conclude if trespassers are touching contaminated soils at the site. The nature and extent of soil contamination are not known. Future changes to land use may lead

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[1] EPA's acceptable increased risk of developing cancer ranges from developing 1 additional cancer case in 10,000 people exposed to 1 additional case for every 1,000,000 people exposed ($1\times10^{-4}$ to $1\times10^{-6}$).

to increased contact with the soil. More soil sample data will be collected during EPA's upcoming RI.

**Basis for Decision.** Most of the former MGP footprint and industrial locations are now covered by asphalt. People are not able to contact most of the contaminated soils. However, a small portion of the former MGP is not covered. Trespassers may come into contact with contaminated soils in this area. More sampling and information on future land use is needed to fully assess if current or future health threats exist.

**Next Steps.** DOH recommends the following:

- Site access be restricted and signed appropriately.
- Nature and extent of contamination in surface soils be characterized.
- Future land use be determined based on risks of disturbing remaining contaminants or recontamination of remediated areas.

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**Conclusion 4.** DOH cannot conclude if people are being exposed to contaminants from eating fish or shellfish harvested at the site. Shellfish and fish tissue data are needed to assess any potential health threat.

**Basis for Decision.** Though uncommon, residents reported stories of people fishing off the bluff along the site. Commercial shellfish harvest in the area and recreational shellfish harvest on nearby public beaches have been closed for many years. DOH closed these areas because of combined sewer overflow releases and status as an active harbor. The intertidal area near the site is not expected to reopen for shellfish harvest. However, the site is situated within the Suquamish Tribe's usual and accustomed (U&A) subsistence fish and shellfish harvest areas. Sediments are contaminated at the site (see conclusion #2) and the extent of contamination is not known. Fish and shellfish tissue sampling and analysis are needed to determine if a health threat exists.

**Next Steps.** To protect the Suquamish tribal members, DOH recommend that EPA consider developing a fish and shellfish sampling and analysis plan.

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**Conclusion 5.** DOH cannot conclude if people are being exposed to contaminants in blackberries collected at the site. Neither soil samples near blackberry bushes nor blackberry potential contaminant data are available to assess this potential health threat.

**Basis for Decision.** Many concerns were brought forward regarding the blackberries that grow on the site at the end of Pennsylvania Avenue. Some residents have been eating these berries for many years. No soil or berry samples have been taken from these areas.

**Next Steps.** DOH recommends the following:

- Signs are placed advising people to refrain from eating fruit grown at the site until more is known about the contaminants in the soil and berries.
- More sampling of soil be conducted where berries grow and berries be analyzed for potential contaminants of concern.

**Conclusion 6.** No one is drinking the contaminated groundwater located in the vicinity of the site. No harm is expected.

**Basis for Decision.** The City of Bremerton has never had public drinking water wells in the vicinity of the site. Thus, the people in residences and businesses in the area are not drinking groundwater contaminated by releases at the site.

**Next Steps.** No further action is required.

## *For More Information*

A copy of this public health assessment will be provided to EPA, Washington State Department of Ecology (Ecology), Washington State Department of Natural Resources (DNR), current and past owners, current tenants, City of Bremerton, the Suquamish Tribe, Kitsap Public Health District, and the Kitsap Regional Library in downtown Bremerton.

A copy of this public health assessment report will be placed on the DOH web site assessment webpage: http://www.doh.wa.gov/consults. If you have any questions about this health consultation contact Lenford O'Garro at 360-236-3376 or 1-877-485-7316 at Washington State Department of Health.

For more information about ATSDR, contact the Center for Disease Control and Prevention (CDC) Information Center at 1-800-CDC-INFO (1-800-232-4636) or visit the agency's web site at www.atsdr.cdc.gov.

# Purpose and Statement of Issues

The purpose of this public health assessment is to: 1) determine whether chemical releases from the Bremerton Gasworks Superfund site pose a public health threat, 2) recommend appropriate actions to protect public health, and 3) identify data gaps where additional sampling may be needed to better assess health risks. The Bremerton Gasworks Superfund site centers around a former manufactured gas plant (MGP) that operated from 1930 to 1963. Other past and current industrial activities adjacent to the former MGP may have also contributed to contamination.

Washington State Department of Health (DOH) prepared this public health assessment under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). This health assessment is mandated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. On September 15, 2011, U.S. Environmental Protection Agency (EPA) proposed to place the Bremerton Gasworks site in Bremerton, Washington on the National Priorities List (NPL) in accordance with Section 105 of CERCLA 42 United States Code (U.S.C.) 9605. The NPL is EPA's list of the nation's most contaminated hazardous waste sites, also known as Superfund sites. ATSDR's goal is to conduct health assessment activities for all sites proposed for inclusion on the NPL. On May 10, 2012, EPA officially listed Bremerton Gasworks site on the NPL.

This document is the first in a two step process: 1) This **initial/public comment release** report determines immediate health concerns and assists EPA in deciding if further sampling is needed to assess health risks. This report also provides the opportunity for community members, stakeholders, and other agencies to comment or ask questions that may not have previously been addressed; and 2) A **final report** that includes responses to public comments. These reports will be available on the DOH website and at the Kitsap Regional library in Bremerton, Washington. The initial/public comment and final reports will be available on the ATSDR website.

# Background

## Site Description

The Bremerton Gasworks Superfund site is located in West Bremerton, Kitsap County, Washington. The site is approximately one mile north by northwest of downtown Bremerton and the ferry dock (Figure 1). It lies along the south shoreline of the Port Washington Narrows less than a half mile west of the Warren Avenue Bridge. The site has a gentle north-facing slope with bluffs approximately 40–50 feet above sea level. The Port Washington Narrows connect Dyes Inlet to Sinclair Inlet. Sinclair Inlet drains into the Puget Sound.

**The formal boundaries of the site have yet to be determined by EPA.** Data collected during the remedial investigation (RI) and cleanup feasibility study (FS) will help determine all the sources, nature, and extent of contamination. In addition to the operations at the former MGP, other past and current industrial activities may have contributed to the contamination at the site. **For this assessment, the term 'site' refers to the upland, shoreline, and waterway areas near the former MGP footprint. It also includes nearby locations of current and past industrial activities (Figure 1).**

Figure 1. Bremerton Gasworks Superfund area including site-related Parcels (A–F), former manufactured gas plant boundary, and state aquatic lands in Bremerton, Kitsap County, Washington.

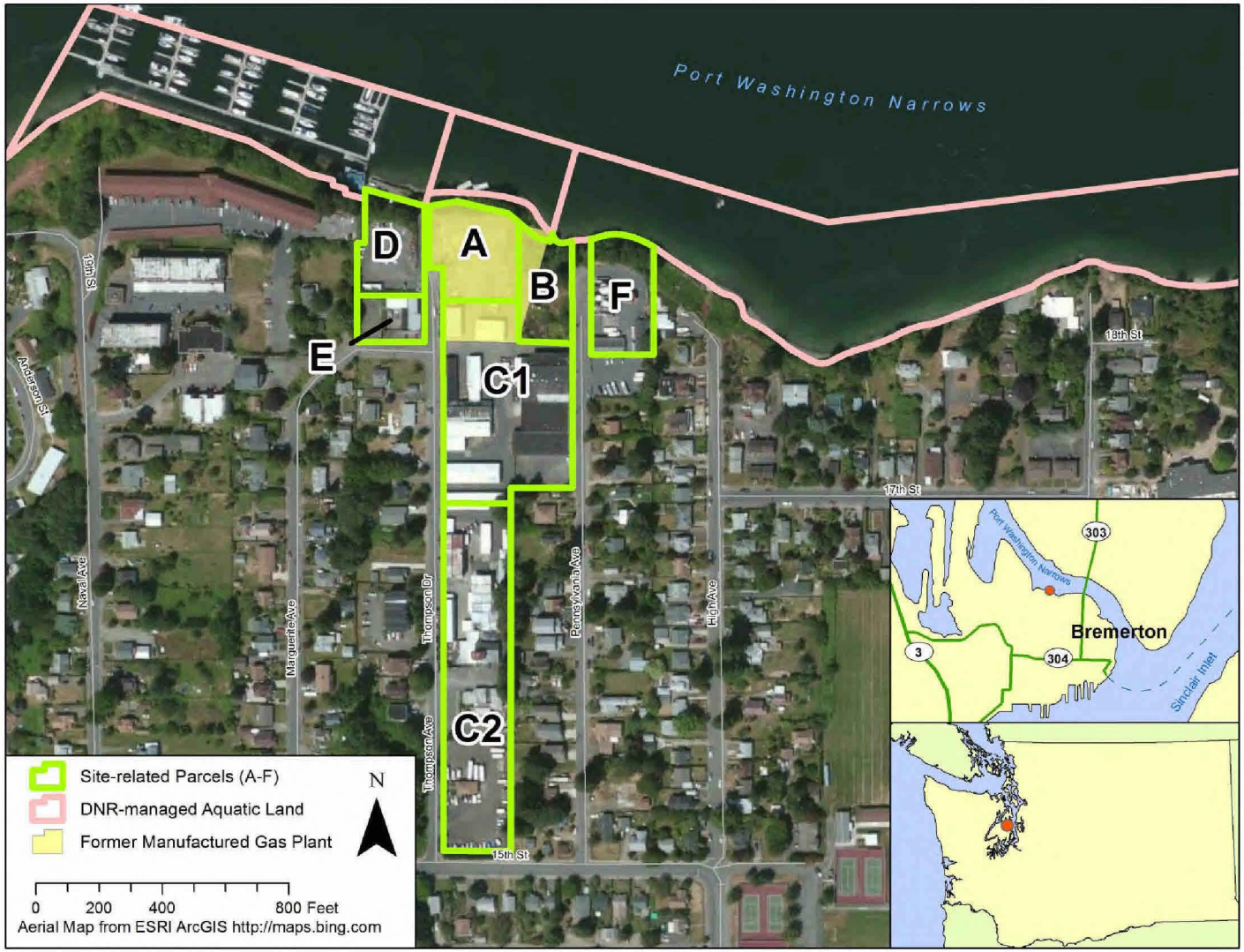

Table 1 provides a list of parcels with known past or current business operations that may have contributed to contamination.

**Table 1**. Parcel identification and industrial activities in the area of the Bremerton Gasworks Superfund site, Bremerton, Kitsap County, Washington.

| Parcel | Parcel Number | Current Activity | Past Activity |
|---|---|---|---|
| **A** | 3711-000-001-0409<br>address not available | Storage (vehicles and implements) | Gas production, former product dock, metal fabrication (cutting fitting, welding, electroplating, sandblasting, and painting) |
| **B** | 3741-000-022-0101<br>address not available | Vacant | Gas production, bulk fuel distribution, former product dock, industrial and/or municipal landfill, metal salvage, and repair of ship parts |
| **C** | **C1** 3711-000-001-0607<br>1723 Pennsylvania Avenue | Storage, light industrial activity (e.g., welding) | Gas production, storage, industrial activities (sheet metal shaping, pipe fitting, plumbing storage and supply, pier manufacturing, welding, building and repair of boat parts, electrical contracting, manufacture of granite countertops, etc.) |
| | **C2** 142401-2-025-2008<br>1512 and 1550 Thompson Drive | Storage, light industrial activity (e.g., welding) | Fabrication of concrete blocks, sewer pipes, and manholes; concrete storage; concrete covering of pier floats |
| **D** | 3711-000-010-0002<br>1805 Thompson Drive Building B | Marina parking lot and upland boat storage | Marina parking lot and upland boat storage; former product pipeline; former product dock |
| **E** | 3711-000-009-0005<br>1701 Thompson Drive | Vacant | Bulk fuel distribution; furniture fabrication; marine propeller electrical repair and parts supplier |
| **F** | 3741-000-001-0007<br>1702 Pennsylvania Avenue | Bulk fuel distribution (diesel) | Bulk fuel distribution, former product pipeline and dock |

**Note:** Site boundary has not yet been determined by the U.S. Environmental Protection Agency; operation information from site documents (Anchor 2011 (1), Ecology and Environment 2009 (2), Hart Crowser 2007 (3) and current owners; parcel information from Kitsap County Assessor (http://kcwppub3.co.kitsap.wa.us/ParcelSearch/ ).

Residential areas border these parcels on the east, west, and south. Thompson Drive and Pennsylvania Avenue are owned and operated by the City of Bremerton. A combined storm sewer overflow outfall runs from Pennsylvania Avenue and discharges approximately 30 yards offshore of the site. The site is located within the Suquamish Tribe's usual and accustomed (U&A) fishing and shell fishing area. Within the U&A, the tribe has treaty-reserved fishing and shell fishing rights. The tribe co-manages fishery resources with the state of Washington.

The intertidal and subtidal lands in this area are state-owned aquatic land managed by Washington State Department of Natural Resources (DNR). This includes the land along the

shoreline that is exposed and submerged with the ebb and flow of tides. The shoreline is mostly accessible when water is at four feet above mean lower low water [2] (+4) and below.

### *Current Conditions and Operations*

The following bullets describe known current uses on the parcels listed in Table 1 and shown in Figure 1. A brief description of parcel conditions that limit or impact human exposure to site contaminants is also provided. Access to Parcels A, B, and C1 are within a fence with locked entrance.

1. **Parcel A:** Paved area used for vehicle and implement storage (0.83 acres). The shoreline banks are steep and have large concrete retaining blocks along the water's edge. The bluffs have discarded creosote-treated wood pilings lying against the slopes underneath the brush. At the edge of the bluff, a strong creosote-like odor can be detected.
2. **Parcel B**: Area is vacant, unpaved, and largely overgrown with brush (0.6 acres). The southern edge of the parcel has two cement foundations that once supported ten above ground storage tanks (ASTs) (see historical operations below). The two cement foundations now contain standing water/dried mud. There is a fence along Pennsylvania Avenue and access is through Parcel C1. Jersey barriers (modular concrete road barriers) separate Parcel B from Parcels A and C1. Along the west side of the parcel, a former unpaved access road leads toward the shoreline. Unrestricted foot access from the shoreline in this area shows indications of trespasser habitation.
3. **Parcel C1**: Area is paved with seven buildings used for storage and light industrial activities (2.1 acres). Tenants have access through a locked fenced entrance. Motorized access to Parcels A and B are also through this entrance.
4. **Parcel C2**: Area is paved with four buildings used for storage and light industrial activities (2.47 acres). Tenants have access through a locked fence.
5. **Parcel D:** Area provides paved marina parking (0.65 acres) and moderately restricted shoreline access. The Port Washington Marina is located in the Narrows next to this parcel and runs 81 active boat slips.
6. **Parcel E**: Area is paved with vacant buildings (0.33 acres). The southeast portion of the parcel has cement foundations and exterior pipe connections. These once supported ASTs of the former bulk fueling facility (see historical operations below).
7. **Parcel F**: Area has three buildings and contains a paved bulk diesel fueling facility with six active ASTs (0.77 acres).

### *Historical Operations*

*Bremerton Gasworks (Former MGP).* The former MGP operations are a source of primary concern at the site. The former MGP covered **Parcel A, the west of Parcel B, and north of Parcel C1** (Figures 1–3). Under several different owners, this plant provided manufactured gas to the City of Bremerton customers for lighting, heating, and cooking. The MGP structures were originally constructed to extract gas from coal using the carbureted water gas process (3). This process injected steam through an incandescent bed of coke or coal. The water gas produced was

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[2] Mean lower low water (MLLW) is the average height of the lower low waters over a 19-year period. Lower low water is the lower of the two low waters tides of the day.

then fed into a carburetor where it was enriched with light hydrocarbons. It is unknown what fuel was used to enrich the water gas. However, petroleum oil-based feed stocks commonly used included naptha; gas oils (diesel, heating, and fuel oils); and residual oils.

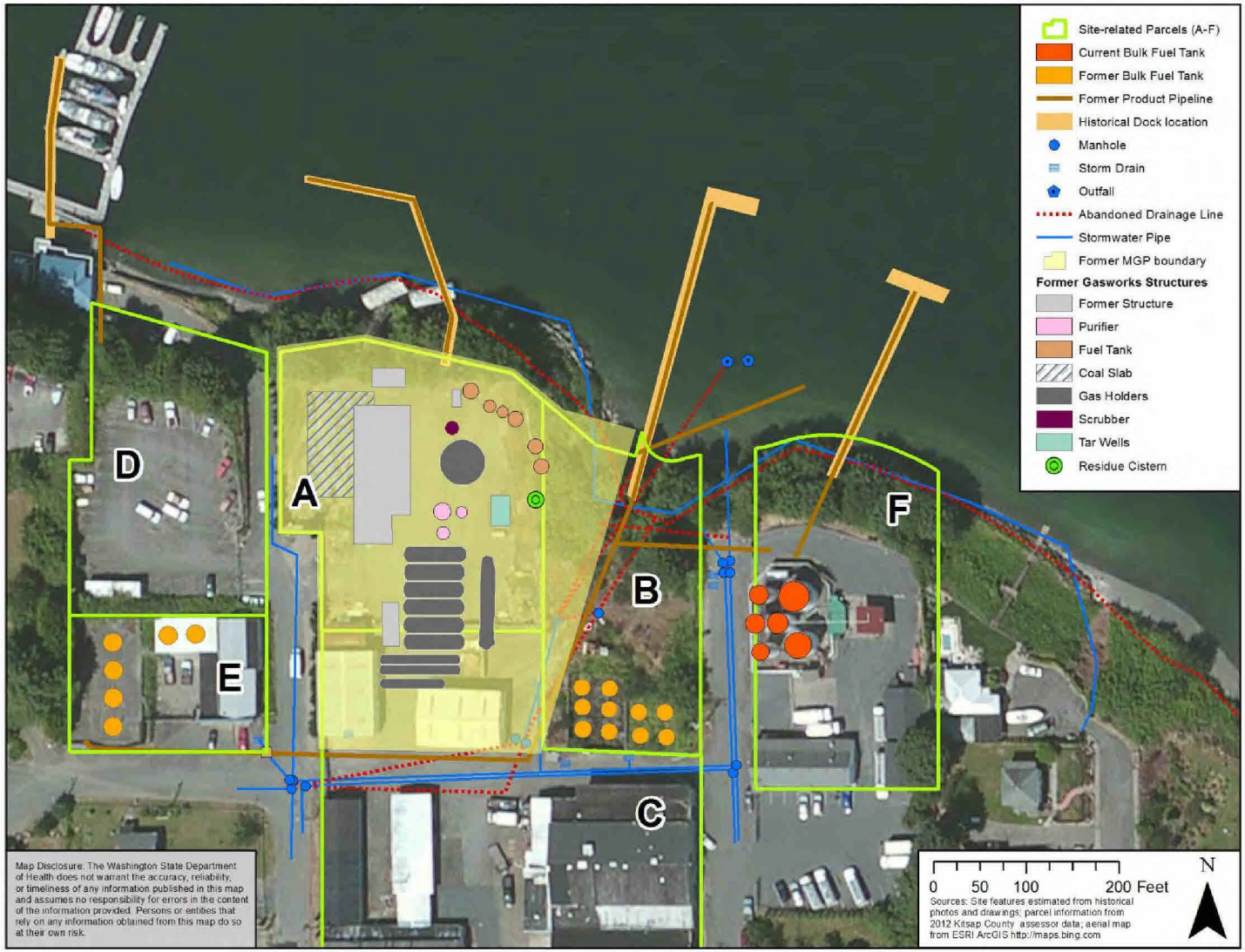
It was reported in 1942 that wood chips were used to remove the tar from the end product (3;4). The "tar-laden wood chips" and the "soot from the water gas machine" were disposed of at the edge of the plant near the oil storage tanks. These byproducts were used to fill a gully on what is presumed to be Parcel B. The tar emulsion was dumped in shallow pits dug at random in the ground. It is not known when these practices started or ended.

Figure 2 demonstrates actual structure configuration and boundaries of the former gasworks plant on a historical photo from the 1950s. Figure 3 provides a more detailed, close-up view of the former structures. These structures included a coal storage area; water gas generator; winch; gas holder and gas tanks; diesel, oil, and gasoline tanks; purifiers and scrubbers; tar well; residue cistern; and numerous underground pipes. Figure 2 shows three piers servicing the area.

Figure 2. Historical aerial photo of the Bremerton Gasworks Superfund site area in Bremerton, Kitsap County, Washington.


The MGP used a carbureted water gas process from 1930 to 1956. From 1956 to approximately 1963, Cascade Natural Gas Corporation produced gas at the facility by blending propane and air (3;5). Over the duration of the plant's operational period, the former MGP maintained approximately 17 petroleum liquid and gas ASTs. According to aerial photographs, plant operations ceased in the late 1960s to the early 1970s. Dismantling of facility structures commenced by 1971 (3).

Figure 3. Former structures of the manufactured gas plant and bulk fueling facilities near the site, Bremerton, Kitsap County, Washington.



*Landfill Activity.* Historical photos indicate the shoreline of **Parcel B** has significantly changed over time. These changes clearly demonstrate that this area has been filled. Most fill activities occurred between 1963 and 1971 (3). No records were available to identify sources of the fill material. The bluff at the end of Pennsylvania Avenue is very steep and has a well used path. This path leads to an area where a rope is necessary to go down to the shoreline. At the bottom of the path, debris from former waste dumping is emerging from the bluff and shoreline sediment. Of concern is a rusted metal tank located adjacent to the path and hidden by brush. A person could very easily fall in or on the tank and become seriously injured.

*Bulk Fuel Facilities.* Three bulk fuel facilities operated separately from the MGP and stored petroleum fuels in ASTs. The product arrived by barge and was transferred to ASTs via above and below ground pipelines, and then distributed from the ASTs (3;5). Use of the three or four former piers was consolidated over time and two or more facilities shared a single pier in later years. All former piers have been removed. It is unknown if the underground distribution pipelines still exist or if product still remains in them. The facilities were or are located on:

- **Parcel B.** Fuel facility was located adjacent to the former MGP. Ten ASTs were on site through the 1940s. Ownership and specific facility operations are unknown. The tanks were removed by the mid 1990s. In 2003, the current owner attempted to remove an underground storage tank (UST) without a permit. Washington State Department of Ecology (Ecology) has no record of USTs or removals on this parcel. It is unknown if the UST is still present.
- **Parcel E.** Six ASTs, built by Atlantic Richfield Company (ARCO), were operated by several different owners/tenants from 1942 to 1992. When ARCO operated the facility, the four ASTs on the western border were labeled as oil tanks (2;3). The plant was dismantled between the late 1980s to the early 1990s and became a furniture business until 1998, followed by a wholesale marine electronic equipment company. Ecology has no record of USTs or removals on this parcel.
- **Parcel F.** Six ASTs are currently in use by SC Fuels. The footprint of this distribution facility has changed little since the 1940s. From 1947 to 1968, the ASTs were used for petroleum products or waste oil (3). The facility now distributes biodiesel. Ecology lists four USTs as removed from the facility. Prior to removal, one UST contained unleaded gasoline, two contained leaded gasoline, and one contained waste oil.

*Penn Plaza Storage LLC.* This storage facility is located on Parcels A, C1, and C2. Much of the property has storage units that contain personal or industrial items. Some industrial activity by tenants has occurred or is occurring on these parcels. Historical operations include:

- Metal fabrication (cutting, fitting, welding, sandblasting, painting, and manufacturing of containment vessels) (Lee Fabricators).
- Electroplating operation.
- Sheet metal operation.
- Electrical contractor.
- Building and repairing ship parts.
- Boat repair.
- Concrete float (pier) fabrication.

- Concrete fabrication and storage (blocks, sewer pipes, and manholes).

*State-Owned Aquatic Lands.* A complete review of DNR-managed activities along the shoreline of the site is beyond the scope of this document. Several sources may have contributed to contamination present on the shoreline. These include:

- Known and unknown effluent drain pipes from the former MGP.
- Unknown effluent drain pipes from other industrial operations.
- Contaminated groundwater released from underground seeps.
- Surface water runoff.
- Combined sewer overflow releases.
- Product and/or fuel spills from vessels.
- Releases from industrial and municipal wastes from Parcel B.
- Boats (i.e., in the adjacent marina, traveling in the Narrows, abandoned on shoreline).
- Unknown chemicals in the two abandoned ballast tanks.
- Creosote-treated pilings from former piers.

## Environmental Investigations

The following environmental investigations have occurred at the site and are listed in chronological order. Data from some of these investigations were used to evaluate the nature and extent of contamination:

In 1992, Ecology inspected Lee Fabricators, a former metal fabrication business in operation since 1986 on **Parcel A** (3). The business was inspected in response to an initiative from Ecology's Sinclair and Dyes Inlet Action Program. Ecology identified two contamination issues:

- One to two inches of uncontained sandblast grit leftover from cleaning metals prior to painting. Grit was high in metal content and entering surface runoff.
- Storage of accumulated paint sludge containing methyl ethyl ketone used to clean the paint guns.

In 1993, Ecology inspected Pier 44 Construction and CB Concrete Products located on **Parcels C1 and C2** (3). In 1994, as a result of lack of improvements of the following observations, the site was listed on Ecology's Confirmed and Suspected Contaminated Sites list:

- At CB Concrete, Ecology identified uncontained oil leaks, piles of uncovered waste concrete which drained to storm water runoff, a large pile of empty stacked fiberglass drums, and oil drums without secondary containment.
- At Pier 44 Construction, Ecology identified uncontained concrete and a dark stain on the floor from diesel used as a releasing agent from the molds.
- At Lee Fabricators, Ecology again noted uncontrolled accumulation of sandblast grit in storm water runoff and improper storage of waste oil.
- During electroplating operations at an unknown location, illegally discharged substances were disposed of into storm drains.

In 1995, DNR observed unpermitted building of ship parts and reclamation activities on **Parcels A and B**. DNR requested that Ecology perform a Site Hazard Assessment. Unrelated to these activities, a black gooey substance with a creosote odor was identified on the bluff of **Parcel B**. PAHs and metals were determined to be contaminants of concern based on one sediment and three soil samples. Ecology added the site to the state's Hazardous Site List.

In 1998, Ecology performed an initial investigation at **Parcel F**, the current bulk fuel facility located on Pennsylvania Avenue (6). Groundwater and soil samples confirmed the presence of non-halogenated solvents and petroleum products above the Washington State Model Control Act (MTCA) cleanup levels. Pacific Northwest Energy Company entered Ecology's Voluntary Cleanup Program (FS ID 2788449) in 2001. They exited the program in 2009. DOH did not have any site documents at the time of this review. Three leaded and unleaded 10,000-gallon USTs and a 5,000-gallon waste oil UST were removed from the facility in the early 2000s (3;6).

In 2006, EPA awarded the City of Bremerton a Brownfields Assessment grant. At that time, the city and owners wanted to develop **Parcels A and B** as a public access marina (2). Soil contamination has migrated from the soil into the groundwater beneath the site (2). Contamination of the sediments in the Washington Narrows was also identified. Contaminants of concern included PAHs, metals, total petroleum hydrocarbons (TPH), and TPH-associated non-chlorinated solvents. Several waste barrels from these remedial sampling efforts are still located on **Parcels A and B**.

In 2010, Kitsap Public Health District (KPHD) investigated reports of an oily sheen on the shoreline of **Parcels A and B**. The release was from an old pipe filled with what appeared to be leftover coal tar product and contaminated sediment. KPHD reported the information to EPA. EPA contacted the Coast Guard, who installed a containment system and then cut and temporarily plugged the end of the pipe. The Coast Guard and EPA's Superfund Technical Assessment and Emergency Response Team (START) collected and analyzed 30 sediment samples. They identified high PAH contamination covering about 100 square feet extending out 60 feet below the high tide line. (1). The depth of contamination was not determined. EPA entered into an Agreed Order with a former owner, Cascade Natural Gas Corporation, to stop the release. The release came from what appeared to be an abandoned sewer storm water outfall pipe. It was once connected to, or may still be connected to, an abandoned vault. The vault likely received discharge from catch basins on the former MGP footprint on **Parcels A and B** (1). Cascade Natural Gas removed approximately 60 feet of pipe and plugged the end. They excavated sediment up to five feet deep and five feet around where the pipe was removed. The area was filled with clean sand and covered by an absorbent clay mat and large rocks. Because of remaining contamination, the site

**Figure 4**. Contaminated sediments at low tide during October 2010 resulting in emergency action removal of product pipe and sediments Bremerton, Washington (photo courtesy of Kitsap Public Health District).

was proposed to EPA's NPL in September 2011 and listed in May 2012. EPA is preparing to initiate a more in depth remedial investigation and feasibility study (RI/FS).

## Natural Resources

*Climate.* In general, the Puget Sound Lowland climate is characterized by mild, wet winters and warm, dry summers. Temperatures do not vary dramatically between the winter and summer. Winter temperatures typically range from 30°F to 50°F, and summer temperatures range from 50°F to 70°F. Precipitation is seasonal with two thirds of the rain falling between November and March. Rain is characterized as frequent and low-intensity with long-duration patterns. Precipitation in the Puget Sound Lowlands, which includes the Bremerton area, averages about 43 inches per year. Snow is rare. Winter storms can be associated with high winds and prevailing winds are from the south/southwest. Storm surges in low-lying coastal areas occur, especially when aligned with higher tides.

*Geology and Marine Water Resources.* The surface geology of the Puget Sound Lowlands consists mainly of glacial, alluvial, and marine sediments. Little bedrock is exposed. The typical soil in the area is Alderwood, formed from glacial till (5). Surface water and storm water flows to the city storm drain which flows into the Narrows. Surface water and storm water can also flow from Parcels C1 and A onto Parcel B then directly onto the shoreline.

The Port Washington Narrows, north of the property, is a 3-mile channel connecting Dyes Inlet to Sinclair Inlet. Sinclair Inlet drains into Puget Sound. This channel is considered a harbor area. This is a relatively deep, narrow channel with strong tidal currents and bluff-backed beaches. Tidal flows drive strong currents through the Narrows at approximately four knots. The daily cycle of tides in Puget Sound includes two unequal high tides and two unequal low tides. From day to day, the height and time of the tide varies depending on the lunar cycle. The lowest and highest tides occur near the summer and winter solstices. The extreme low tides of late fall and early winter occur near midnight. Low tides permitting access to the shoreline during the day occur about 60% of the year (218 out of 365 days) [3] mostly between March and September. At this location, tides usually range from -3 feet below to +14 feet above the average of the lowest tides recorded at the closest tide station.

*Groundwater.* Sand and gravel deposited during the last ice age compose the aquifers in the area. Based on topography and local drainage patterns, shallow-seated groundwater flows to the north or northeast (5). From previous reports, depth to groundwater is estimated at 10 to 20 feet deep (5).

The City of Bremerton has never had public drinking water wells in the vicinity of the site. Thus, the people in residences and businesses in the area are not drinking water contaminated by releases at the site. When Bremerton incorporated in 1901, the population was drinking from

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[3] Access to the shoreline occurs when the water is less than four feet above mean lower low water (4+ tide). Mean lower low water is the average of the extreme low tides recorded at a tide station. The closest National Oceanic and Atmospheric Administration (NOAA) tide station is at Tracyton, Dyes Inlet, Estimates are days in 2011with 4+ tides or lower that occur between 7 a.m. and 7 p.m.
http://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=9445901

local wells and springs. It is not known if private wells were located near the site at that time or when these owners started using city water. Bremerton has provided citizens with public drinking water from several surface water sources from 1917 to present. Currently, the Union River supplies 60% of this water. The other 40% is supplied by 13 production wells that were added to the public water supply in the 1940s. None of these wells are near the site and are miles away. Private wells are not allowed to be used within the Bremerton Water Service Area. For more information on Bremerton's water sources see the city's website.[4]

*Fish.* A number of fish common to the Puget Sound are presumed to be in the Port Washington Narrows. Tidal currents are swift within the Port Washington Narrows and may be a deterrent to fishing. Local residents have observed fishing from boats in the Narrows and from the shoreline. This is not a frequent event.

**DOH has set the following fish consumption advisories for the Bremerton area.**[5] Advisories are based on an adult meal size of 8 ounces (227 grams) of uncooked fish.

- Chinook salmon – no more than one meal per week (all of Puget Sound).
- Resident juvenile Chinook salmon (blackmouth salmon) – no more than one meal per month (all of Puget Sound).
- Puget Sound rockfish – no more than one meal per week from Bremerton area and most of Puget Sound. Do not eat Puget Sound rockfish from Sinclair Inlet.
- Yelloweye and canary rockfish – Do not eat.
- English sole and other flatfish – no more than one meal per week from Port Orchard Passage and no more than one meal per month from Sinclair Inlet.

No Puget Sound meal limits have been set for other species of salmon (coho, chum, pink, or sockeye).

*Bivalves (Clams, Oysters, and Mussels).* Shellfish bivalve species known to the area include oysters, mussels, and a variety of clams. DOH and Kitsap Public Health District regularly test shellfish and water for fecal and biological toxins. DOH has closed commercial harvest in the area and recreational harvest on nearby public beaches for many years because of combined sewer overflow outfalls. **Do not eat shellfish from the Bremerton Area.** Several starfish, small crabs, clam shells, and other invertebrates were observed at low tide during the site visit in July 2012.

*Crab and Shrimp.* Dungeness crab (*Cancer magister*) live in the subtidal sediments of the Port Washington Narrows. Spot prawn (*Pandalus playceros*), coonstripe shrimp (*P. danae and P. hypsinotus*) and pink shrimp (*P. eous and P. jordani*) are known to Puget Sound and probably present in the Narrows. DOH has a crab advisory for the Bremerton area. Advisories assume that an adult meal size equals 8 ounces (227 grams) of uncooked crab. **Do not eat Dungeness and red rock crab from the Bremerton area.**

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[4] http://www.ci.bremerton.wa.us/display.php?id=733

[5] http://www.doh.wa.gov/Portals/1/Documents/Pubs/334-104.pdf

## Demographics

The site is located in an urban area of Bremerton. Nearby, there are industries, residences, businesses, schools, and the Port of Washington Marina. Bremerton is the largest city on the Kitsap peninsula. It's the home to the Puget Sound Naval Shipyard and U.S. Navy base.

According to the 2010 census, the population in Bremerton is 37,729 which makes up 14% of Kitsap County. A majority of the Bremerton population is white/Caucasian (76.7%). The rest of the population is classified as other race/two or more races (12.9%), African American (6.7%), and Hispanic/Latino (6%). The main language spoken in the area is English (89%), followed by Spanish (4.4%) and Asian languages (4.3%).

The area's economic status falls below the rest of Kitsap County and the state. The average median household income is $38,060, while the county is $59,358 and the state is $56,384. Approximately 14% of the families are below poverty, which is higher than the rest of the county (5.7%) and state (11.8%).

The Suquamish Tribe has "usual and accustomed" fishing rights to the area. According to the 2000 Census, the total population for the Suquamish Tribe is 616 people.

# Discussion

## Exposure Evaluation

The exposure evaluation consists of three components:

1. Understanding the nature and extent of environmental contamination at and around the site,
2. Identifying exposure pathways by evaluating who may be or has been exposed to site contaminants, and
3. Identifying uncertainties and data gaps to be filled that would help understand exposures to people.

### *Nature and Extent of Contamination*

DOH used environmental data collected during several investigations to evaluate the nature and extent of contamination at the site. Figure 5 demonstrates the sample locations of data available from the site. The Environmental Investigations section contains details of these investigations. Tables 2, 3, and 4 summarize detected compounds in sediment, surface soil, and groundwater, respectively.

*Sediments.* Sediment samples from the shoreline have been taken during four investigations.

- In March 1995, one sediment sample (depth unknown) was analyzed for metals and semivolatile organic compounds (SVOCs) during an investigation by Ecology (5;7). These data were not used in the current evaluation. They do not represent current conditions but do identify locations of high contamination not well characterized recently.

- In June 2008, five sediment samples (depth unknown) were analyzed for metals, SVOCs, and total petroleum hydrocarbons – Diesel (TPH-Dx) (2) during the EPA Brownfield assessment.
- In October 2010, 31 sediment samples (30 centimeters (cm) deep) were analyzed for metals, SVOCs, volatile organic compounds (VOCs), and total petroleum hydrocarbons (TPH) during the emergency action removal of the leaking pipe (8). Of these, nine were covered by the interim action placement of a clay mat and rocks.
- In November 2010, samples of removed materials including three sediment samples (30 cm deep) and two samples of sediment/product in the pipe were analyzed for metals, SVOCs, VOCs, and TPH. These data were not used in the current evaluation but identify contaminants of concern.

In general, PAHs are elevated on the shoreline and the extent and depth are not well characterized. Several compounds were analyzed with high detection limits. Limited data suggest that metals are not of concern, but more information is needed. Table 2 summarizes detected compounds in sediment used in this evaluation.

*Soils.* Soil samples were taken during two investigations at the site. Table 3 summarizes detected compounds in surface soil at the site.

- In May 2008, during EPA's Brownfield assessment, core samples were taken up to 45 feet deep at the 7 surface soil locations (2). Cores were separated into 5-foot samples and analyzed for metals, SVOCs, VOCs, and TPH-Dx.
- In March 1995, during the initial investigation by Ecology, three soil samples (depth unknown) were analyzed for metals and SVOCs (7). These data were not used in the current evaluation. They do not represent current conditions but do identify locations of high contamination not well characterized.

PAHs were present in elevated concentrations at a few of the subsurface locations on parcel B. PAHs and TPH were detected up to 35 feet below ground surface (2). The only metal compound found at higher concentrations was thallium in deeper soils (15 - 40 feet below ground surface). As noted in the Exposure Pathways section, the only people that would be exposed to chemicals in subsurface soils would be workers during excavation work. These workers are protected under the Occupational and Safety Health Administration (OSHA). Therefore, these exposures are not evaluated here.

*Groundwater.* During the Brownfield assessment in June 2008, 6 groundwater samples were analyzed for metals, SVOC, VOC, and TPH-Dx (2;9;10). Table 4 summarizes detected compounds in groundwater. As noted in the Exposure Pathway section, people are not drinking this contaminated groundwater. However, this water can be discharging into the narrows.

Figure 5. Sample locations from previous investigations at the Bremerton Gasworks Superfund site, Bremerton, Kitsap, Washington.

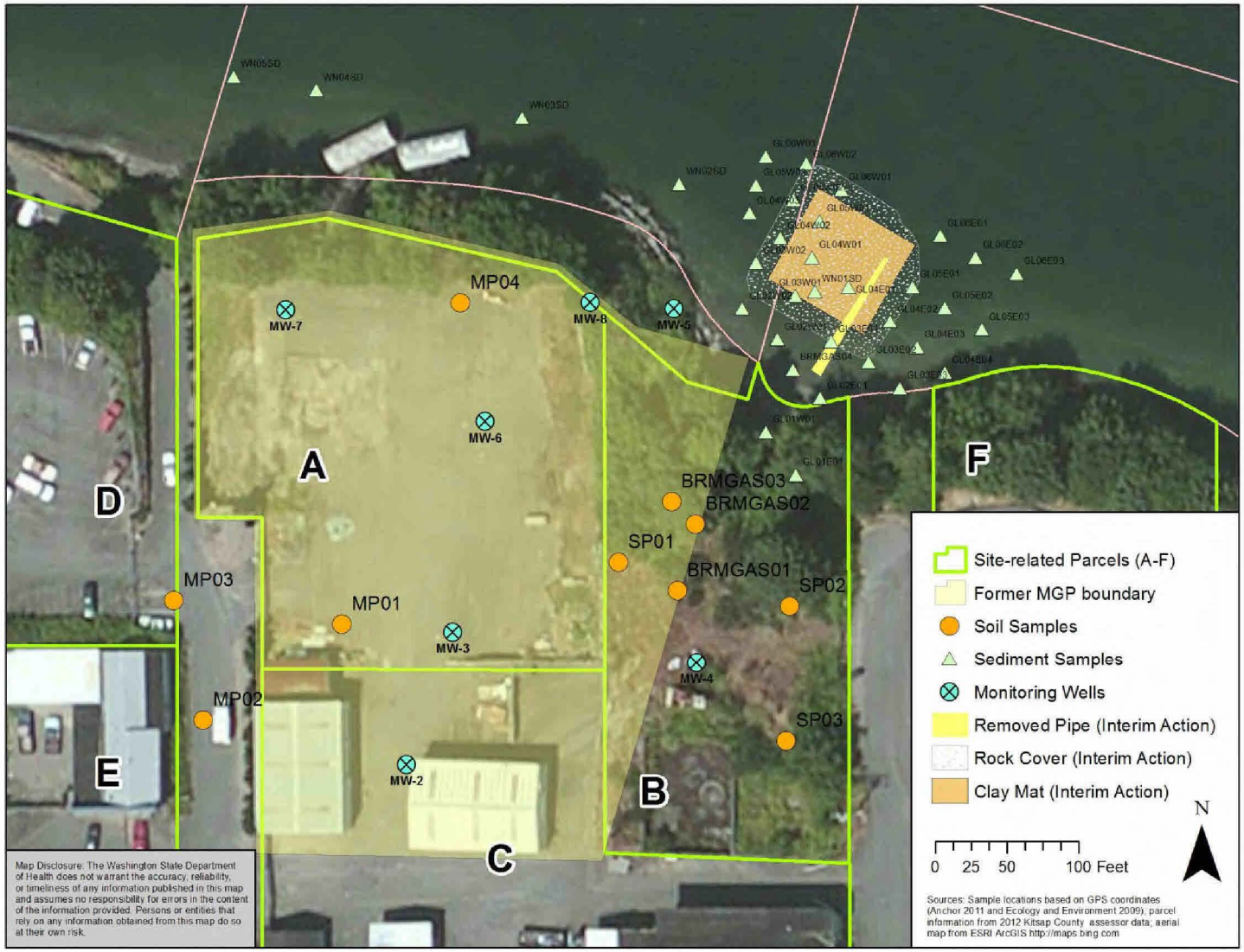

**Table 2.** Chemicals in **intertidal sediments** exceeding health-based comparison values, Bremerton Gasworks Superfund site, Kitsap County, Washington.

| Chemical [a] | Number Detected / Total Sampled [b] | Soil CV [c] (mg/kg) | Type of CV | Range of Concentrations (mg/kg) | Number Detected (and non-detected) greater than CV |
|---|---|---|---|---|---|
| Semivolatile Organic Compounds | | | | | |
| **Benz(a)anthracene** [e] | 28/36 | 0.48 [d] | CREG/RPF | 0.16–69 | **26 (7)** |
| **Benzo(a)pyrene** [e] | 26/36 | 0.096 | CREG | 0.26–76 | **26 (10)** |
| **Benzo(b)fluoranthene** [e] | 32/36 | 0.12 [d] | CREG/RPF | 0.13–110 | **32 (4)** |
| **Benzo(k)fluoranthene** [e] | 18/36 | 3.2 [d] | CREG/RPF | 0.19–60 | **2 (5)** |
| **Benzo(g,h,i)perylene** [e] | 11/36 | 10.7 [d] | CREG/RPF | 0.16–32 | **2 (5)** |
| **Chrysene** [e] | 29/36 | 0.96 [d] | CREG/RPF | 0.17–80 | **27 (6)** |
| **Dibenz(a,h)anthracene** [e] | 5/36 | 0.0096 [d] | CREG/RPF | 0.047–15 | **5 (31)** |
| **Fluoranthene** [e] | 34/36 | 1.2 [d] | CREG/RPF | 0.34–110 | **31 (2)** |
| **Indeno(1,2,3-cd)pyrene** [e] | 20/36 | 1.4 [d] | CREG/RPF | 0.15–72 | **9 (14)** |
| **Total cPAH BaP-EQ** [f] | 36/36 | 0.096 [d] | BaP CREG | **0.93–351** [e] | **36** |

**Source:** Anchor 2011 (1); E&E 2009 (2)

**Notes:**

[a] Bolded chemicals have detected concentrations in sediments that require further risk evaluation.

[b] Table includes detected chemicals and chemicals with detection limits above the CV. Compounds not detected not listed.

[c] ATSDR CVs based on child soil exposures were used for screening (CVs for sediment exposures have not been developed). To be conservative, soil CVs reflect residential exposures and are expected to overestimate sediment exposures on the shoreline.

[d] BaP CREG was used as a surrogate compounds chemicals that have no CV. BaP CREG was divided by potency factor relative (RPF) to BaP as presented by EPA 2010 (11) to obtain the CV.

[e] PAHs associated with carcinogenic effects (cPAHs). For each sample, each PAH is multiplied by potency factor relative (RPF) to BaP as presented by EPA 2010 (11). These are summed and presented as the Total cPAH BaP Equivalent (BaP-EQ).

[f] Per ATSDR, CV is health-based for non-carcinogenic effects only, not carcinogenic effects. CREG CV is below background.

**Table 2 Abbreviations:**

| | |
|---|---|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BaP | Benzo(a)pyrene |
| BaP-EQ | Benzo(a)pyrene equivalents |
| cPAH | Polycyclic Aromatic Hydrocarbons that have carcinogenic adverse effects |
| CREG | ATSDR Cancer Risk Evaluation Guide |
| CV | Health-based comparison value (unless otherwise indicated) |
| EPA | U.S. Environmental Protection Agency |
| mg/kg | milligrams of chemical per kilograms of sediment |

**Table 3**. Chemicals in **surface soil** samples (0–5 feet bgs) exceeding health-based comparison values, Bremerton Gasworks Superfund site, Kitsap County, Washington.

| Chemical [a] | Number Detected / Total Sampled [b] | Soil CV [c] | Type of CV | Range of Concentrations (mg/kg) | Number Detected (and non-detected) greater than CV |
|---|---|---|---|---|---|
| Semivolatile Organic Compounds (mg/kg) | | | | | |
| **Benzo(a)anthracene** [e] | 5/7 | 0.48 [d] | CREG/RPF | 0.48–1.6 | **2** |
| **Benzo(a)pyrene** [e] | 5/7 | 0.096 | CREG | 0.57–2.5 | **2** |
| **Benzo(b)fluoranthene** [e] | 5/7 | 0.12 [d] | CREG/RPF | 0.43–1.8 | **2** |
| **Benzo(k)fluoranthene** [e] | 5/7 | 3.2 [d] | CREG/RPF | 0.0009 JQ– 2.2 | |
| **Benzo(g,h,i)perylene** [e] | 5/7 | 10.7 [d] | CREG/RPF | 0.0011U– 2.4 | |
| **Chrysene** [e] | 4/7 | 0.96 [d] | CREG/RPF | 0.52–3.9 | **2** |
| **Dibenzo(a,h)anthracene** [e] | 5/7 | 0.0096 [d] | CREG/RPF | 0.78–1.1 U | **1(1)** |
| **Fluoranthene** [e] | 6/7 | 1.2 [d] | CREG/RPF | 0.0016U–12 J | **1** |
| **Indeno(1,2,3-cd)pyrene** [e] | 5/7 | 1.4 [d] | CREG/RPF | 0.0013U –2.0 | **1** |
| **Total PAH BaP Equivalents** [f] | 6/7 | 0.096 [d] | BaP CREG | **0.3–13.6** [e] | **3** |
| Metals (mg/kg) | | | | | |
| **Thallium** | 4/7 | 0.78 | RSL | **2.2 JQ –4.1** | **2** |
| Total Petroleum Hydrocarbons (mg/kg) | | | | | |
| **Heavy oil range** | 3/7 | 2,000 | MTCA | 25U–**4,700J** | **1** |

**Source:** E&E 2009 (2)

**Notes:**

[a] Bolded chemicals have detected concentrations in surface soil that people could come in contact with. Further evaluation is not done in this report until more information on extent and future land use is available.

[b] Chemicals analyzed but not detected are not listed. However, table includes chemicals with detection limits above the CV.

[c] ATSDR CVs based on child residential soil exposures.

[d] BaP CREG was used as a surrogate compounds chemicals that have no CV. BaP CREG was divided by potency factor relative (RPF) to BaP as presented by EPA 2010 (11) to obtain the CV.

[e] PAHs associated with carcinogenic effects (cPAHs). For each sample, each PAH is multiplied by potency factor relative (RPF) to BaP as presented by EPA 2010 (11). These are summed and presented as the Total cPAH BaP Equivalent (BaP-EQ).

[f] Per ATSDR, CV is health-based for non-carcinogenic effects only, not carcinogenic effects. CREG CV is below background.

**Abbreviations:**

| | |
|---|---|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BaP-EQ | Benzo(a)pyrene equivalents |
| cEMEG | ATSDR Environmental Media Evaluation Guide based on chronic exposures (>365 days) based on MRL |
| cPAH | Polycyclic Aromatic Hydrocarbons that have carcinogenic adverse effects |
| CREG | ATSDR Cancer Risk Evaluation Guide |
| CV | Health-based comparison value (unless otherwise indicated) |
| EPA | U.S. Environmental Protection Agency |
| J | Chemical positively identified but outside of quality control limits and considered an estimate |
| JQ | Chemical detected below the reporting limit but above the detection limit and considered an estimate |
| mg/kg | milligrams of chemical per kilograms of sediment |
| MTCA | Washington State Model Toxics Control Act cleanup regulation |
| RSL | EPA Regional Screening Level |
| U | Value undetected at the detection limit given |
| bgs | Below ground surface |

Table 4. Chemicals in **groundwater** samples exceeding health-based drinking water comparison values, Bremerton Gasworks Superfund site, Kitsap County, Washington.

| Chemical [a] | Number Detected / Total Sampled [b] | Drinking Water CV (µg/L) [c] | Type of CV | Range of Concentrations (µg/L) | Number Detected (and Non-detected) greater than CV |
|---|---|---|---|---|---|
| **Semivolatile Organic Compounds** | | | | | |
| **Benz(a)anthracene** [e] | 4/5 | 0.024 [d] | CREG/RPF | 0.05 U–0.66 | **2** |
| **Benzo(a)pyrene (BaP)** [e] | 2/5 | 0.0048 | CREG | 0.05 U–1.1 | **2** |
| **Benzo(b)fluoranthene** [e] | 2/5 | 0.006 [d] | CREG/RPF | 0.05 U–0.59 | **2** |
| **Benzo(k)fluoranthene** [e] | 3/5 | 0.16 [d] | CREG/RPF | 0.7 | **1** |
| **Benzo(g,h,i)perylene** [e] | 2/5 | 0.53 [d] | CREG/RPF | 0.12–0.82 | **2** |
| **Chrysene** [e] | 3/5 | 0.048 [d] | CREG/RPF | 0.068–1.1 | **2** |
| **Dibenz(a,h)anthracene** [e] | 1/5 | 0.00048 [d] | CREG/RPF | 0.05U–0.5U | **1** |
| **Fluoranthene** [e] | 4/5 | 0.060 [d] | CREG/RPF | 0.12–3.7 | **4** |
| **Indeno(1,2,3-cd)pyrene** [e] | 2/5 | 0.069 [d] | CREG/RPF | 0.090–0.40 | **2** |
| **Total PAH B(a)P Equivalent** [f] | 4/5 | 0.0048 [d] | CREG | **0.61U–3.0** [e] | **4** |
| **Methylnaphthalene, 2-** | 5/5 | 40 | RMEG | 0.11–**170J** | **1** |
| **Trimethylbenzene, 1,2,4-** | 1/5 | 15 | RSL | 0.5U–**16** | **1** |
| **Trimethylbenzene, 1,3,5-** | 1/5 | 87 | RSL | 0.5U–**98** | **1** |
| Metals (ug/L) | | | | | |
| **Arsenic** | 8/8 | 0.023 | CREG | **0.04–4.1** | **5** |
| **Barium** | 8/8 | 2,000 | cEMEG | 0.10–**3,140** | **2** |
| **Beryllium** | 4/8 | 4 | MCL | 0.37–**7.6** | **2** |
| **Cadmium** | 5/8 | 1 | cEMEG | 0.16–**3.9** | **4** |
| **Chromium [hexavalent chromium]** | 8/8 | 9 | cEMEG | 0.05–**1,670** | **4** |
| **Lead** | 5/8 | 15 | MCL | 1.0 U–**268** | **3** |
| **Manganese** | 8/8 | 500 | RMEG | 0.32–**25,600** | **4** |
| **Vanadium** | 5/8 | 100 | iEMEG | 3.7 JQ–**717** | **3** |
| Total Petroleum Hydrocarbons | | | | | |
| **Diesel range** | 5/6 | 500 | MTCA | **510–5,500** | **2** |
| Volatile Organic Compounds | | | | | |
| **Benzene** | 3/6 | 0.64 | CREG | 0.25U–**3,100J** | **3** |
| **Naphthalene** | 3/6 | 100 | LTHA | 0.25UJ –**1,800** | **1** |
| **Trichloroethene** | 2/6 | 0.76 | CREG | 0.25U–**25 UJ** | **0 (1)** |

**Source: Anchor 2011 (1); E&E 2009 (2)**

**Notes:**

[a] Bolded chemicals have detected concentrations that exceeded CV.

[b] Chemicals analyzed but not detected are not listed. However, table includes chemicals with detection limits above the CV.

[c] ATSDR CVs based on child residential soil exposures.

[d] BaP CREG was used as a surrogate compounds chemicals that have no CV. BaP CREG was divided by potency factor relative (RPF) to BaP as presented by EPA 2010 (11) to obtain the CV.

[e] PAHs associated with carcinogenic effects (cPAHs). For each sample, each PAH is multiplied by potency factor relative (RPF) to BaP as presented by EPA 2010 (11). These are summed and presented as the Total cPAH BaP Equivalent (BaP-EQ).

[f] Per ATSDR, CV is health-based for non-carcinogenic effects only, not carcinogenic effects. CREG CV is below background.

**Abbreviations:**

| | |
|---|---|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BaP-EQ | Benzo(a)pyrene equivalents |
| cEMEG | ATSDR Environmental Media Evaluation Guide based on chronic exposures (>365 days) based on MRL |
| cPAH | Polycyclic Aromatic Hydrocarbons that have carcinogenic adverse effects |
| CREG | ATSDR Cancer Risk Evaluation Guide |
| RPF | Relative Potency Factor |
| CV | Health-based comparison value (unless otherwise indicated) |
| EPA | U.S. Environmental Protection Agency |
| iEMEG | ATSDR Environmental Media Evaluation Guide based on intermediate exposures (90–365 days) based on MRL |
| MCL | EPA Maximum Contaminant Level |
| MTCA | Washington State Model Toxics Control Act cleanup regulation |
| ppm | parts per million |
| RMEG | ATSDR Reference Dose Media Evaluation Guide for non-carcinogenic adverse effects |
| LTHA | EPA Lifetime Health Advisory for drinking water |
| RSL | EPA Regional Screening Level |
| U | Value undetected at the detection limit given |
| UJ | Associated value is an estimated |
| J | Chemical positively identified but outside of quality control limits and considered an estimate |
| JQ | Chemical detected below the reporting limit but above the detection limit and considered an estimate |
| ug/L | micrograms of chemical per liter of water |

### *Exposure Pathways*

In order for a chemical to harm human health, people must come into contact with the chemical. An exposure pathway describes how a chemical moves from a source and comes into contact with people. An exposure pathway is specific to when it occurred or will occur: the past, present, or future. An exposure pathway has five elements:

1. a source of contaminants;
2. a release mechanisms into water, soil, air, or the food chain;
3. an exposure point or area;
4. an exposure route (ingestion, dermal contact, or inhalation); and
5. a potentially exposed population.

Exposure pathways may be "completed," "potential" or "eliminated." A completed pathway has all five elements in place and occurring. A potential pathway has one or more of the elements unknown. If one of the five elements is not in place and occurring, the pathway is eliminated and not evaluated. Table 5 describes the completed, potential, and eliminated exposure pathways for the Bremerton Gasworks Superfund site.

DOH identified the following **completed pathways** at the site:

- Currently and in the past, residents, owners, and workers come in contact with contaminated sediment on the shoreline.
- Currently and in the past, inhalation of vapors from creosote-treated pilings on Parcel A is occurring. Workers, site trespassers, and residents may be exposed to chemicals being released into the air from this source.
- In the distant past, unrestricted access of the site resulted in owners, local residents, and workers contacting contaminants in soil. During the site visit, workers and owners described specific areas black with contaminated oily soil.

Table 5. Exposure Pathways for the Bremerton Gasworks Superfund site, Bremerton, Kitsap County, Washington.

| Pathway Name | Exposure Pathway Elements | | | | | Time Frame | Pathway Evaluation |
|---|---|---|---|---|---|---|---|
| | Source | Media | Point of Exposure | Route of Exposure | Potentially Exposed Population | | |
| Surface Soil | Past disposal of MGP waste; Leakage from storage tanks; Landfill debris from municipal and gasworks activities; Runoff from industrial activities. | Soil | Surface soil and on slope to shoreline | Ingestion; Dermal Contact | Trespassers; Site workers | Past | Completed |
| | | | | | | Present | Potential |
| | | | | | Local residents; Trespassers; Recreational visitors | Future | Potential |
| Subsurface Soil | Past disposal of MGP waste; Leakage from storage tanks; Landfill debris from municipal and gasworks activities; Abandoned product pipes | Subsurface Soil | Subsurface soils | Ingestion; Dermal Contact | Site workers | Past | Potential |
| | | | | | | Present | Potential |
| | | | | | | Future | Potential |
| Surface Water | Contaminated soils released into storm water runoff; Waste product released into the Narrows | Surface Water | Storm water runoff | Ingestion; Dermal Contact | Trespassers | Past | Potential |
| | | | | | | Present | Potential |
| | | | | | Local residents; Trespassers; | Future | Potential |
| Air | Release of volatiles from waste in surface soil and surface water runoff; Creosote- treated pilings on shoreline | Air | Air near or on property | Inhalation | Local residents; Trespassers; Recreational visitors; Tribal harvesters | Past | Completed |
| | | | | | | Present | Completed |
| | | | | | | Future | Potential |
| Public Water Supply | Past deposit of MGP waste in wells, soils; Leakage from storage tanks | Municipal Water Supply | Tap water | Ingestion | Past users of municipal water Supply | Past | Completed |
| | | | None (different water source) | None | None (different water source) | Present | Eliminated |
| | | | | | | Future | Eliminated |
| Private Water Supply | Past deposit of MGP waste in wells or soils; Leakage from storage tanks | Groundwater (Private Wells) | Well water | Ingestion | Past local residents with private wells | Past | Potential |
| | | | None (different water source) | None | None (different water source) | Present | Eliminated |
| | | | | | | Future | Eliminated |

Table 5 (continued).

| Pathway Name | Exposure Pathway Elements | | | | | Time Frame | Pathway Evaluation |
|---|---|---|---|---|---|---|---|
| | Source | Media | Point of Exposure | Route of Exposure | Potentially Exposed Population | | |
| Sediment | Seeps from contaminated groundwater; Release of product from abandoned pipes; Creosote-treated pilings; Surface runoff from facility; Fuel and oil spills from boats formerly docked in the area | Sediment | Sediments on shoreline | Ingestion; Dermal Contact | Trespassers | Past | Potential |
| | | | | | | Present | Potential |
| | | | | | Local residents; Trespassers; Recreational visitors; Tribal harvesters | Future | Potential |
| Food Chain (Biota) | Past deposit of MGP waste in soils, water, or the narrows; Landfill debris from municipal and gasworks activities; Contaminated storm runoff from facility | Food | Blackberries | Ingestion | Local residents; Trespassers; Recreational visitors (exposure limited to late summer and fall) | Past | Potential |
| | | | | | | Present | Potential |
| | | | | | | Future | Potential |
| Food Chain (Biota) | Seeps from contaminated groundwater; Release of product from abandoned pipes; creosote-treated pilings; Surface runoff from facility; Fuel and oil spills from boats formerly docked in the area | Food | None | None | None | Past | Eliminated |
| | | | | | | Present | Eliminated |
| | | | Shellfish | Ingestion | Local residents; Trespassers; Recreational visitors; Tribal harvesters | Future | Potential |
| Food Chain (Biota) | Seeps from contaminated groundwater; Release of product from abandoned pipes; creosote-treated pilings; Surface runoff from facility; Fuel and oil spills from boats formerly docked in the area | Food | None | None | None | Past | Eliminated |
| | | | | | | Present | Eliminated |
| | | | Fish | Ingestion | Local residents; Trespassers; Recreational visitors; Tribal harvesters | Future | Potential |

MGP manufactured gas plant

DOH identified the following **potential pathways** at the site:

- Occasionally and in the past, transient populations reside near areas where bluff seeps of oil have been reported. No exposures have been reported. However, there is uncertainty as to where the contamination is located relative to inhabited areas. These trespassers may come into contact with surface soils, surface water, or sediments that are contaminated. Kitsap Public Health District reported forcing trespassers to leave the site.
- Current and future workers at the site may come in contact with surface or subsurface soil contamination.
- Currently, children and local residents harvest blackberries grown at the bottom of Pennsylvania Avenue adjacent to Parcel B. This location has not been tested for contaminants in soils. Some contaminants are known to accumulate in berries.
- Future use of the property may increase access to the shoreline. This would increase daily exposures of children and local residents to contaminants in surface soils and shoreline sediments.
- In the future, shellfish harvest could occur at low tide by residents, recreational visitors, and tribal subsistence harvesters. Eventually combined sewer overflows will be contained reducing fecal contamination in shellfish. Though unlikely, public beaches in the Narrows may be opened for shellfish harvest.
- Current and future use of the Narrows for fishing is unknown. Potential areas of sediment contamination may exist near former dock structures and seeps. Fish living nearby may be contaminated. Eating these fish could result in increased exposures of contaminants which accumulate in fish.

Some exposures are not occurring at the site or are extremely unlikely. DOH eliminated the following exposure pathways.

- Currently, in the past, and in the future, contaminated groundwater at the site is not used as a drinking water source. Bremerton does not have source wells in the area. No private wells in the area exist. No springs on site have been identified. No exposure is expected.
- In the past and currently people may not harvest shellfish near the site. For many years, area commercial harvest and recreational harvest on nearby public beaches have been closed by DOH. No exposure is expected.

***Data Gaps***

Additional data are necessary for a more definitive assessment of human exposures and possible health effects. Sampling recommended to be focused on locations where people live, spend time, and play.

*Sediment.* The intertidal shoreline will be used in the future by residents, tribal members, or recreational visitors. The extent of contamination is not known. The intertidal sediment is well characterized near the mat and rocks placed in 2010 during the emergency action. A limited number of samples beyond this area have been taken. Sediment samples have only been taken between Thompson and Pennsylvania Avenues. The depth of contamination is not known. Nothing is known about the sediments further than approximately 120 feet offshore below the low-water mark. It is possible that effluent from the former MGP was released directly into the Narrows. Most effluent would have been carried away with the tide. Heavier residues from the

gasification process may have drifted down into the sediments of the narrows. Contaminants in these sediments may impact shellfish and fish that may be harvested and eaten.

The nature of contamination has only been partially identified. Of the sediment samples taken, VOCs and SVOCs have been well characterized, though some had high detection limits. The PAH data for sediment samples are adequate. Only five sediment samples were measured for metals. More information about the extent of metal contamination along the shoreline is needed. Groundwater at the site appears to be contaminated with several metals which may be released to the shoreline (see Groundwater under the Data Gaps section).

*Surface Soil.* Trespassers and homeless people may temporarily live at the site and likely come in contact with surface soil. Surface soils in areas frequented by homeless people have not been sampled. The nature and extent of contamination has not been identified. There are not enough soil data to estimate future exposures, especially if the asphalt is removed. Soil beneath blackberries harvested at the end of Pennsylvania Avenue has not been sampled. Of some concern are potential leaks in the areas beneath former product pipelines.

*Subsurface Soil.* Other than excavation or construction workers, people do not come in contact with subsurface soils. Thus, subsurface soil data, for the most part, are not useful for estimating human exposures. Limited subsurface sampling indicated areas below Parcel B are largely contaminated with MGP product residues. Residues were detected up to 35 feet below the surface. The extent of contamination is not well characterized.

*Groundwater.* People are not drinking the contaminated groundwater at the site (see Exposure Pathways section). Thus direct exposure to groundwater does not occur and more groundwater information will not help understand human exposures. Little information could be found regarding the relationship between the groundwater beneath the site and seeps or springs along the shoreline. Multiple anecdotal stories of seeps have been reported, some of which have been "oily." It is not clear where, or if, the contaminated groundwater is being released along the shoreline, thus the sources of contamination have not been identified.

*Air.* People walking on the shoreline or working at the site would be exposed to chemicals in the air. No air sampling has been conducted at the site. Creosote-like smells were observed along the shoreline. Sources for these smells should be identified and depending on the source, air sampling and analysis should be considered. Extensive wind movement along the Narrows will dilute chemicals in the air. It is unlikely that air would stagnate or remain in one location. However, exposure to chemicals in the air cannot be estimated at this time.

*Biota.* The Suquamish Tribe has U&A rights to harvest shellfish and fish in the Washington Narrows. During the site visit, clam shells and crab carcasses were observed on the beach during low tide. No information on the ecological sustainability of these and other species as a resource is available. No shellfish or fish chemical data in tissue are available. More information is needed to better understand exposures through consumption of fish and shellfish.

Nearby residents eat blackberries grown at the shoreline, particularly at the end of Pennsylvania Avenue. Concerns have been raised about potential contamination of berries. Berries have been shown to accumulate PAHs and some metals which have been reported at the site. Neither soil

samples nor berry samples have been sampled and analyzed; therefore, exposures cannot be evaluated.

*Other Contaminants.* Other contaminants were not analyzed; however, they may be present at the site. Dioxin and furan compounds may have been created during the combustion of fuel oils and gasification residues. Because of the boat repair and part fabrication that occurred at the site, soil and sediment should also be analyzed for tributyltin. Tributyltin was frequently used in marine paints.

*Nearby Sources and Locations.* Data from sampling to determine the nature and extent of contamination by other sources were not available. In particular, soil data from near the current and former bulk fuel centers at Parcels E and F were not available. The bulk fuel facility on Parcel F has had environmental investigations done (2). The contaminants identified petroleum contaminants in subsurface soils (2). The catchment drain network delivers site storm water at two locations distal to the site (see Figure 3). More data are needed to understand the transport of contaminants off the site.

## Health Effects Evaluation

### *Screening Analysis*

The goal of the screening analysis is to identify chemicals of potential concern at the site. Environmental data are compared with health-based CVs. CVs are chemical concentrations in soil, sediment, or water. CVs concentrations are set at levels below which no health effects are expected from exposure (e.g., touching, breathing, or swallowing). CVs incorporate chemical toxicity information and assumptions of daily exposure.

CVs are conservative and non-site specific and set to protect the most sensitive population, usually children. CVs are based on health guidelines with uncertainty or safety factors applied to ensure that they protect public health. **Chemicals detected below their CV** are not expected to result in health effects from exposure. These chemicals are not considered further in the public health assessment process. **Chemicals detected above their CV**, do not necessarily represent a health threat. These chemicals will undergo site-specific evaluation to determine if health effects are expected to occur. CVs are not intended to be used as environmental clean-up levels.

CVs can be based on either carcinogenic or non-carcinogenic effects. Cancer CVs are calculated from EPA's oral cancer slope factor (CSF). CVs based on cancerous effects account for a lifetime exposure (70 years). They are based on an estimated excess lifetime cancer risk of 1 extra case per 1,000,000 people exposed. Non-cancer CVs are calculated from ATSDR's Minimal Risk Levels (MRLs) or EPA's Reference Doses (RfDs). Some chemicals have both a cancer CV and non-cancer CV. When this happens, the lower of these values is used to be protective. Chemicals without a CV use a surrogate CV of a chemical that has similar structural and physiochemical features. CVs include Environmental Media Evaluation Guides (EMEGs), Cancer Risk Evaluation Guides (CREGs), and Reference Dose Media Evaluation Guides (RMEGs), MTCA state cleanup levels, and EPA Regional Screening Levels (see definitions in the glossary in Appendix A).

Groundwater and soil data were adequate for screening. As a conservative approach, the screening analysis will compare sediment concentrations with soil CVs. Table 2 summarizes chemicals in sediment that exceed soil CVs. PAHs associated with carcinogenic effects (cPAHs) are of concern and will be evaluated further for resident, trespasser, and visitor exposures. Neither soil nor water exposures are evaluated further at this time. Soil data are not adequate to complete a full evaluation; more data are needed. Groundwater exposures are not occurring; so, they are not evaluated further. Though not evaluated further, Tables 3 and 4 summarize chemicals that exceed soil and water CVs, respectively.

The PAH chemical class includes hundreds of individual chemicals. Most PAHs are fat-loving compounds, generated from the incomplete combustion of organic matter, including oil, wood, and coal. They are found in materials such as creosote, coal, coal tar, and used motor oil. Thus, their presence at the site near the former MGP in Bremerton is not surprising. Dietary sources make up a large percentage of PAH exposure in the U.S. population (8). Grains and smoked or barbequed meat and fish contain relatively high levels of PAHs. The majority of dietary exposure to PAHs for the average person comes from ingestion of vegetables and grains (cereals). PAHs are often evaluated for adverse health effects as a group. This is based on structural similarities, metabolism, and toxicity.

### *Non-carcinogenic Effects*

Exposure to PAHs in sediments is estimated to be lower than levels where observable non-carcinogenic effects have been reported, thus non-carcinogenic adverse effects were not considered for further assessment. Many of these compounds were several orders of magnitude below the non-carcinogenic CVs.

### *Carcinogenic Effects*

Approximately 41% of men and women born today will be diagnosed with cancer at some time during their lifetime) (12).[6] Many factors influence the development of cancer and are not considered in this report. Some chemicals have the ability to cause cancer; others do not. Cancer risk estimates represent the increased chance (probability) of developing cancer if exposure to a chemical occurs. To estimate the risk of developing cancer the dose is multiplied by the chemical's cancer potency factor. Cancer potency factors, also known as a cancer slope factors, are chemical specific and sometimes mixtures. Some cancer potency factors are derived from human population data and others are derived from laboratory animal studies. Sometimes the doses in animal studies are much higher than encountered in the environment. Use of animal data requires extrapolation of the cancer potency from high dose studies down to low-level exposures. This process involves much uncertainty.

With some exceptions, current regulatory practice assumes there is "no safe dose" of a carcinogen. In other words, any dose of a carcinogen will result in some additional cancer risk. The validity of "no safe dose" assumption for all cancer-causing chemicals is not clear. Some chemicals must exceed a certain dose threshold before initiating cancer. For such chemicals,

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[6] According to the National Cancer Institute (NCI) based on 2007–2009 incidence rates.

cancer risk estimates are not appropriate. Unless a chemical has been shown to have a threshold, DOH assumes that no threshold exists.

DOH describes cancer risks estimated for site-related contaminants in qualitative terms. Terms used to describe the increased risk of developing cancer include moderate, low, very low, slight, and insignificant. To better understand these terms, consider how big the population size at the site must be to see additional cases of cancer. For example, a low cancer risk would be associated with 1 additional case in 10,000 people exposed over a lifetime ($1\times10^{-4}$). A very low estimate reflects 1 additional cancer case in 100,000 people exposed over a lifetime ($1\times10^{-5}$). These estimates are within the range DOH considers acceptable risk. EPA uses this target range of risk as part of their decision making process to determine if action is warranted. That range is 1 excess cancer case per 10,000 people exposed to 1 excess cancer case per 1,000,000 people exposed ($1x10^{-4}$ to $1x10^{-6}$) in these scenarios. Ecology considers cancer risk up to 1 additional case of cancer in 100,000 people to be acceptable risk.

**Estimated Cancer Risk**

Cancer risk estimates do not reach zero no matter how low the level of exposure to a carcinogen. Terms used to describe this risk are defined below as the number of excess cancers expected in a lifetime:

| Term | | Number of Excess Cancers |
|---|---|---|
| Moderate | approximately equal to | 1 in 1,000 |
| Low | approximately equal to | 1 in 10,000 |
| Very Low | approximately equal to | 1 in 100,000 |
| Slight | approximately equal to | 1 in 1,000,000 |
| Insignificant | less than | 1 in 1,000,000 |

Because cPAHs in sediment exceed the soil comparison values, a more in-depth analysis of exposure and toxicity is warranted. Estimating exposure requires identifying how much, how often, and how long a person may come in contact with sediments. The mathematical equations used to estimate how much of a substance a person may contact sediments are based on their actions or habits. These equations are described in Appendix C. Potential health risks were evaluated for future sediment exposures to children or adult residents playing in sediments on the shoreline and for visitors or trespassers.

The most studied PAH is benzo(a)pyrene (BaP). Several different sets of factors for assessing carcinogenic potency of other PAHs relative to BaP have been published. Commonly used approaches rely on cPAH potency data many years old and were limited to seven PAHs (8;13). These PAHs were classified by EPA as probable human carcinogens (Class B2). This classification is a result of *sufficient* evidence of carcinogenicity in animals but *inadequate* evidence in humans.

The methodology for estimating cancer risk from exposure to PAH mixtures sums the PAHs together. First, each PAH is multiplied by its relative potency factor (RPF). This factor scales the concentration relative to the potency of BaP. These modified concentrations are then summed as the BaP-Equivalent (BEQ) concentration. In 2010, EPA released draft report updating the RPFs of selected cPAHs in mixtures (8;14). This report considered more recent data and a wider range of cPAH compounds. Cancer risk is then estimated using the current oral cancer slope factor for BaP.

Using the 95% upper confidence limit of the average sediment concentration (159 mg/kg cPAH BEQ) the following estimated cancer risk estimates were calculated for touching or accidently ingesting sediment from the shoreline at the site during daytime low tides (See Appendix C):

- For every 1,000 local residents playing or recreating on the beach sediments at low tide during the day for a lifetime, there is an increased lifetime risk of developing *5 additional cancer cases* ($5.3\times10^{-3}$);
- For every 1,000 people visiting the beach sediments during the three summer months for a lifetime, there is an increased lifetime risk of developing *2 additional cancer cases* ($2.2\times10^{-3}$);
- For every 10,000 adults (ages 16 years and higher) trespassing onto the site and going onto beach sediments three days a week for a lifetime, there is an increased lifetime risk of developing *6 additional cases of cancer cases* ($5.5\times10^{-4}$).

## Evaluation of Health Outcome Data

Evaluation of health outcome data (e.g., mortality and morbidity) in public health assessments are considered per ATSDR guidance (15). The main requirements for evaluating this type of data include:

- a completed pathway,
- high contaminant levels to result in measurable health effects,
- sufficient number people in the completed pathway for effects to be measured, and
- a health outcome database in which disease rates for the population of concern can be identified.

This site does not meet the requirements for including an evaluation of these data. Although a completed exposure pathway exists, the exposed population is not sufficiently defined or large enough.

## Child Health Considerations

DOH recognizes that infants and children may be more vulnerable to exposures than adults in communities with contamination issues. This vulnerability is a result of the following factors. Children are more likely:

- To play outdoors in contaminated areas by disregarding signs and wandering into restricted locations.
- To bring food into contaminated areas resulting in more hand to mouth exposures.
- To receive higher doses of a contaminant because they are smaller.
- To breathe dust and soil because they are shorter and therefore, closer to the ground.
- To sustain permanent damage if exposures occur during critical growth stages of the developing body.
- To have underdeveloped functional capacity of various organ systems and/or metabolic pathways. This can result in different rates of detoxification.

Health-based CVs were derived from health guidelines that incorporate a high level of protectiveness for children and sensitive individuals. It is likely that children will play or dig in sediments at public access points or shoreline residences. Thus, the exposure scenarios in this public health assessment treated children as the most sensitive population being exposed. In addition, an age-dependent adjustment factor is used to protect children 2 years old and younger and 3–6 year olds. Because of child-specific behaviors, estimated cancer risks for child residents and visitors 6 years old and younger have exposures that contribute to two-thirds of the lifetime cancer risk (up to 78 years).

# Community Health Concerns

The purpose of this section is to document and respond to current, specific community health concerns. DOH conducted two site visits, one in July and one in August 2012. DOH is working with EPA to develop a community involvement and communication plan. EPA and DOH conducted community interviews on September 18, 2012. This meeting provided an opportunity to meet with residents to discuss concerns regarding the site. On October 10, 2012, DOH met with the mayor of Bremerton, Public Works Director, community outreach, and two city council members. Staff discussed the Public Health Assessment process and ways to best communicate results of the report. The community has been invited to previous meetings regarding site activities during the EPA Brownfields Assessment. EPA and the Coast Guard posted signs informing residents of actions that occurred during the emergency removal in 2010. The release into the Narrows at that time raised concerns of on-going contamination from the site.

Community members, owners, and other members of the public brought forward the following health-related concerns and questions:

1. **Are the cancers that people have in the neighborhood caused by the release of chemicals from the site?**

Cancer is a term used for diseases in which abnormal cells divide without control and sometimes invade other tissues. Cancer develops over many years and has many causes. Several factors, both inside and outside the body, contribute to cancer development. Often, doctors cannot explain why one person develops cancer and another does not. Likewise, we cannot determine if any cancers in the neighborhood were caused by a chemical released from the former MGP or other industrial operations. Each chemical is associated with specific types of cancer. The individual chance that someone will develop cancer in response to a particular, single environmental exposure depends on 1) the potential of the chemical to cause cancer, 2) how long or how often that person was exposed, 3) genetic makeup, 4) lifestyle, and 5) pre-existing conditions. Each person is exposed differently.

Research shows that risk factors increase the chance that a person will develop cancer. The most common risk factors for cancer include: growing older, tobacco, sunlight, ionizing radiation, viruses, bacteria, hormones, family history of cancer, alcohol, poor diet, lack of physical activity,

being overweight, and some environmental chemicals. About 41% of men and women born today will develop cancer at some time during their lifetime [7] (12).

**2. Is the water we drink contaminated from the site?**

No. Your drinking water comes from the City of Bremerton. The City of Bremerton's public water supply is from Union River (60%) and production wells distant from the site (40%). The City has provided public drinking water since the 1940s.

**3. Are the blackberries at the bottom of Pennsylvania Avenue safe to eat?**

DOH does not know if contaminants from the site are in the blackberries at the bottom of Pennsylvania Avenue. Blackberries grow everywhere at the bottom of Pennsylvania Avenue and on the accessible areas of the Sesko property. In August, September, and October children and local residents collect and eat these berries. DOH recommends collecting and eating berries from a number of locations, not just one.

DOH recommends that the soils in which the blackberries grow be analyzed to see if contaminants are present and available for the plants to absorb. If contaminants are present, we recommend analyzing the blackberries at the bottom of Pennsylvania Avenue.

**4. Can we eat the shellfish collected on the shoreline or fish caught near or at the site?**

For many years, DOH has closed commercial shellfish harvest and recreational harvest on nearby publicly owned beaches. The closure is because of combined sewer overflow releases resulting in fecal contamination on beaches. DOH does not recommend eating shellfish harvested near the site. DOH does not know if contaminants from the site are in shellfish that live in the Narrows. However, contaminants have been found in the sediments these shellfish live in.

DOH also does not recommend eating fish caught near the site. DOH does not know how far away the contamination has moved from the site. DOH does not have any fish tissue data to know if these chemicals and metals are in the fish that live in the Washington Narrows.

To better address this question, DOH recommends:

- Further sampling and analysis of the sediments to determine the extent of the contamination.
- Replacement of warning signs.
- Sampling and analysis of fish and shellfish expected to be harvested.

**5. Is it safe for tenants of the Penn Plaza Storage to come onsite?**

Yes. Most of the contaminants from the site are below the asphalt or underground and are not easy to come in contact with. The storage property is fenced and locked and most tenants use the buildings briefly for storage or for light industrial activities. Though accessible from the storage

[7] Rate of developing cancer based on 2007-2009 incidence rates from National Cancer Institute (NCI).

area, DOH recommends you do not enter the areas beyond your rented space. There are areas on the site with contaminants on the soil surface.

**6. Are homeless people, who temporarily live at or near the site, exposed to contaminants or at risk of harm?**

During our site visit, we found evidence of habitation and frequent use by trespassers on part of the site. Owners have reported trespassers in the past. From Pennsylvania Avenue, a very steep path leads to the shoreline. The path deviates and allows access to areas of the site that are contaminated. Coming into contact with oily residues, contaminated soil, or contaminated surface water runoff may increase exposures to contaminants. Owners reported 'oily seeps' in the past on the hillside above where homeless people sleep.

A foot path is present from the end of Pennsylvania Avenue down to the shoreline. Kitsap Public Health District has addressed unsafe use of the area in the past and asked people to leave. A rope providing access to the shoreline has been removed a number of times. During the site visit, a rusted metal tank was observed at the bottom of path. The tank opening was covered by bushes and leaves. A person could easily trip onto or fall into the tank resulting in physical injury.

DOH recommends that a sign and fence prohibiting beach access be installed at the site. DOH recommends that physical hazards be reduced either with fencing or removal (for items such as the tank).

**7. What are the big tanks on the shoreline near the site? Are they dangerous?**

These tanks are former ballast tanks from a submarine that were used to allow the vessel to submerge and surface. DNR reported the presence of volatile organic compounds inside the tanks. Kitsap Public Health District did not detect these compounds in the tank in 2010. The tanks are accessible at low tide and tied to the shoreline with a rope. Access to the tanks presents a physical hazard. DOH recommends that these tanks be removed.

**8. If the land is zoned residential or used as a park, what are the health risks for a resident or visitor?**

The future use of the land has not been determined nor has the level of remediation that will occur to reduce risk. EPA is beginning its investigation to determine the nature and extent of contamination from the site. With more soil, sediment, and tissue data a more accurate assessment of health threats will be possible.

**9. Is it safe to swim in the water near the site?**

We do not recommend swimming in the Washington Narrows for several reasons:

- Cold water can quickly incapacitate the best of swimmers.
- Tidal currents are so swift in the narrows that swimmers cannot break free of the current. Swimmers can be easily carried into open waters.
- DOH does not know the extent of contamination in the water or sediments of the Washington Narrows. Contaminants from in sediments can be released into the water column.

DOH does not know if swimming in the Narrows will result in chemical exposures. More data are needed to determine if a health threat exists from this type of exposure.

**10. Are there signs posted about health risks at the site?**

Kitsap Public Health District posted signs on the beach to warn people about the contamination on the shoreline. These signs have been removed by the swift currents moving through the Washington Narrows. DOH recommended that Kitsap Public Health District replace the signs.

# Conclusions

DOH has reviewed the analytical results of soil, groundwater, and sediment samples taken from the site. DOH identified PAHs, some metals, and petroleum hydrocarbons to be chemicals of potential concern. Several data gaps were identified in assessing risks to potentially exposed populations. DOH estimated exposures to PAHs in beach sediments for 1) residents who live adjacent to the site, 2) shoreline visitors during summer, and 3) homeless people who frequently trespass and temporarily live on the site. Other exposure pathways will be addressed in future assessments as more data become available.

DOH reached six conclusions in this public health assessment:

1. Trespassing on the site could result in physical injury. This is an urgent public health hazard. Several physical hazards are present at the site.

2. Touching or accidentally ingesting sediments for more than a year could harm the health of children or adults. PAHs exceed the EPA cancer risk range of $1\times10^{-4}$ to $1\times10^{-6}$.

3. DOH cannot conclude if trespassers are touching contaminated soils at the site. The nature and extent of soil contamination are not known. Future land use may lead to contact with the soil. More soil sample data will be collected during EPA's upcoming RI.

4. DOH cannot conclude if people are being exposed to contaminants from eating fish or shellfish harvested at the site. Shellfish and fish tissue data are needed to assess any potential health threat.

5. DOH cannot conclude if people are being exposed to contaminants in blackberries collected at the site. Neither soil samples near blackberry bushes nor blackberry potential contaminant data are available to assess this potential health threat.

6. No one is drinking the contaminated groundwater located in the vicinity of the site. No harm is expected.

# Recommendations

To protect residents, visitors, and trespassers, DOH recommends the following:

- Physical hazards be removed.

- Until further characterization, site access be restricted based on risks of disturbing remaining contaminants or recontamination of remediated areas.
- Ongoing source(s) of contaminants be identified and removed or mitigated to reduce the potential of exposure.
- People protect their health by not walking or playing on the shoreline near the site.
- Parents monitor their children's behavior while playing outdoors to prevent them from going onto the shoreline.
- Signs be placed advising people to refrain from eating fruit grown at the site until more is known about the levels of potential contaminants in the soil and berries.
- Nature and extent of contamination in surface soils be characterized.
- Future land use be determined based on risks of disturbing remaining contaminants or recontamination of remediated areas.

To protect the Suquamish tribal members, DOH recommend that EPA consider developing a fish and shellfish sampling and analysis plan.

# Public Health Action Plan

Actions Completed

- EPA and DOH conducted community interviews on September 18, 2012.

Actions Underway

- EPA is moving forward with the RI/FS and any interim actions.
- City of Bremerton is installing a sign at the end of Pennsylvania Avenue prohibiting beach access.
- Kitsap Public Health District is facilitating the replacement of signs on shoreline warning people of contamination
- Owner will remove or fence the rusted tank at the foot of the bluff within three months.
- Owner will remove the submarine ballast tanks in collaboration with EPA and Washington State Department of Natural Resources (DNR).
- EPA is facilitating the maintenance of the capped area on the shoreline. The cap consists of an absorbent clay mat covered with large rocks. Maintenance is recommended to continue until the extent of contamination is known and a remedy is determined.
- EPA is facilitating the removal of waste barrels found on Parcel A.

Actions Planned

- DOH is working with EPA to develop a community involvement and communication plan.
- EPA is considering developing sampling plans to collect and analyzing fish, shellfish, and berries.
- DOH will develop a fact sheet that summarizes the findings of this Public Health Assessment. DOH will plan to distribute the fact sheet within two months of the Public Health Assessment being approved.

- DOH will provide copies of this Public Health Assessment to EPA, the Suquamish Tribe, KPHD and concerned parties when the report is approved.
- DOH will be available any time to answer health related questions regarding the Bremerton Gasworks Superfund site.

## Report Preparation

This Public Health Assessment for initial/public comment release on the Bremerton Gasworks Superfund site in Kitsap County, Washington was prepared by the Washington Department of Health (DOH) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner (DOH). ATSDR has reviewed this document and concurs with its findings based on the information presented.

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# Appendix A–Glossary

| | |
|---|---|
| Acute | Occurring over a short time [compare with **chronic**]. |
| Agency for Toxic Substances and Disease Registry (ATSDR) | The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services. |
| Cancer Risk Evaluation Guide (CREG) | The concentration of a chemical in air, soil, or water that is expected to cause no more than one excess cancer in a million persons exposed over a lifetime. The CREG is a *comparison value* used to select contaminants of potential health concern and is based on the *cancer slope factor* (CSF). |
| Cancer Slope Factor (CSF) | A number assigned to a cancer causing chemical that is used to estimate its ability to cause cancer in humans. |
| Carcinogen | Any substance that causes cancer. |
| Chronic | Occurring over a long time (more than 1 year) [compare with **acute**]. |
| Comparison Value (CV) | Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process. |
| Contaminant | A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects. |
| Dermal Contact | Contact with (touching) the skin (see route of exposure). |
| Dose<br><br>(for chemicals that are not radioactive) | The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs. |

| | |
|---|---|
| Environmental Media Evaluation Guide (EMEG) | A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a comparison value used to select contaminants of potential health concern and is based on ATSDR's minimal risk level (MRL). |
| Environmental Protection Agency (EPA) | United States Environmental Protection Agency. |
| Epidemiology | The study of the occurrence and causes of health effects in human populations. An epidemiological study often compares two groups of people who are alike except for one factor, such as exposure to a chemical or the presence of a health effect. The investigators try to determine if any factor (i.e., age, sex, occupation, economic status) is associated with the health effect. |
| Exposure | Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure]. |
| Hazardous Substance | Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive. |
| Ingestion | The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure]. |
| Ingestion Rate (IR) | The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil. |
| Inhalation | The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**]. |
| Inorganic | Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc. |
| Lowest Observed Adverse Effect Level (LOAEL) | The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals. |

| | |
|---|---|
| Maximum Contaminant Level (MCL) | A drinking water regulation established by the federal Safe Drinking Water Act. It is the maximum permissible concentration of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system. MCLs are enforceable standards. |
| Media | Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants. |
| Minimal Risk Level (MRL) | An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see oral **reference dose**]. |
| Model Toxics Control Act (MTCA) | The hazardous waste cleanup law for Washington State. |
| No Observed Adverse Effect Level (NOAEL) | The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals. |
| Oral Reference Dose (RfD) | An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA. |
| Organic | Compounds composed of carbon, including materials such as solvents, oils, and pesticides that are not easily dissolved in water. |
| Parts per billion (ppb)/Parts per million (ppm) | Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE. |
| Reference Dose Media Evaluation Guide (RMEG) | A concentration in air, soil, or water below which adverse non-cancer health effects are not expected to occur. The EMEG is a *comparison value* used to select contaminants of potential health concern and is based on EPA's oral reference dose (RfD). |
| Regional Screening Levels (RSL) | EPA's risk-based tools for evaluating and cleaning up contaminated sites (Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites). |

| | |
|---|---|
| Route of Exposure | The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact]. |

# Appendix B–Data Summary

**Table B1.** Chemical concentration (mg/kg) of **intertidal sediment samples** and health-based comparison values, Bremerton Gasworks Superfund site, Kitsap County, Washington.

| Chemical [a] | Number Detected / Total Sampled [b] | Soil CV [c] (mg/kg) | Type of CV | Range of Concentrations (mg/kg) | Number Detected (and non-detected) greater than CV |
|---|---|---|---|---|---|
| Semivolatile Organic Compounds | | | | | |
| **Benz(a)anthracene** | 28/36 | 0.48 [d] | CREG/RPF | 0.16–69 | 26 (7) |
| **Benzo(a)pyrene** | 26/36 | 0.096 | CREG | 0.26–76 | 26 (10) |
| **Benzo(b)fluoranthene** | 32/36 | 0.12 [d] | CREG/RPF | 0.13–110 | 32 (4) |
| **Benzo(k)fluoranthene** | 18/36 | 3.2 [d] | CREG/RPF | 0.19–60 | 2 (5) |
| **Benzo(g,h,i)perylene** | 11/36 | 10.7 [d] | CREG/RPF | 0.16–32 | 2 (5) |
| **Chrysene** | 29/36 | 0.96 [d] | CREG/RPF | 0.17–80 | 27 (6) |
| **Dibenz(a,h)anthracene** | 5/36 | 0.0096 [d] | CREG/RPF | 0.047–15 | 5 (31) |
| **Fluoranthene** | 34/36 | 1.2 [d] | CREG/RPF | 0.34–110 | 31 (2) |
| **Indeno(1,2,3-cd)pyrene** | 20/36 | 1.4 [d] | CREG/RPF | 0.15–72 | 9 (14) |
| **Total cPAH BaP-EQ [f]** | **36/36** | 0.096 [d] | BaP CREG | **0.93–351 [e]** | **36** |
| Acenaphthene | 5/36 | 3,000 | RMEG | 0.024–15 | |
| Acenaphthylene | 5/36 | 3,000 | RMEG* | 0.048–15 | |
| Anthracene | 4/36 | 15,000 | RMEG | 0.034–15 | |
| Biphenyl, 1,1'- | 4/5 | 2,500 | RMEG | 0.024–0.1 | |
| Bis(2-chloroethyl)ether | 0/36 | 0.64 | CREG | 0.024–15U | 0 (29) |
| Carbazole | 4/36 | 1,300 | RMEG** | 0.024–15 | |
| Chloroaniline, 4- | 0/36 | 200 | RMEG | 0.024–1500U | 0 (27) |
| Dibenzofuran | 4/36 | 78 | RSL | 0.024–15 | |
| Dinitro-2-methylphenol, 4,6- | 0/36 | 200 | iEMEG | 0.048–450U | 0 (6) |
| Dinitrophenol, 2,4- | 0/36 | 100 | RMEG | 0.12–450U | 0 (6) |
| Fluoranthene | 34/36 | 2,000 | RMEG | 0.34–110 | |
| Fluorene | 4/36 | 2,000 | RMEG | 0.012–15 | |
| Hexachlorobenzene | 0/36 | 0.44 | CREG | 0.024-15U | 0 (29) |
| Hexachlorocylclopentadiene | 0/36 | 9 | CREG | 0.024-15U | 0 (27) |
| Methylnaphthalene, 2- | 4/36 | 200 | RMEG | 0.024–15 | |
| Methylphenol, 4- (p-cresol) | 1/5 | 310 | RSL | 0.017–0.024 | |
| Naphthalene | 5/36 | 1,000 | RMEG | 0.017–150 | |
| Nitrolaniline, 4- | 0/36 | 24 | RSL | 0.048–2300U | 0 (31) |
| Nitroso-dimethylamine, N- | 0/36 | 0.014 | CREG | 0.024–0.036 | |
| Nitroso-di-n-propylamine, N- | 0/36 | 0.10 | CREG | 0.024–15U | 0 (31) |
| Pentachlorophenol | 0/36 | 1.8 | cEMEG | 0.024–150U | 0 (31) |
| Phenanthrene [Fluoranthene] | 19/36 | 2,000 | RMEG*** | 0.14–36 | |
| Phthalate, Di(2-ethylhexyl) | 1/36 | 50 | CREG | 0.024–150U | 0 (6) |
| Phthalate, Diethyl | 1/36 | 40,000 | RMEG | 0.024–15 | |

Table B1 (continued).

| Chemical [a] | Number Detected / Total Sampled [b] | Soil CV [c] (mg/kg) | Type of CV | Range of Concentrations (mg/kg) | Number Detected (and non-detected) greater than CV |
|---|---|---|---|---|---|
| Pyrene | 35/36 | 1,500 | RMEG | 0.50–160 | |
| Trichlorophenol, 2,4,5- | 0/36 | 0.64 | CREG | 0.0014–150U | 0 (6) |
| Xylene, o- | 1/5 | 10,000 | cEMEG**** | 0.0014–0.0057 | |
| Metals | | | | | |
| Aluminum | 5/5 | 50,000 | cEMEG | 6020–9030 | |
| Arsenic | 5/5 | 15 | cEMEG | 1.5–5.1 | |
| Barium | 2/5 | 10,000 | cEMEG | 13.3–47 | |
| Beryllium | 5/5 | 100 | cEMEG | 1.9–2.7 | |
| Cadmium | 0/5 | 5 | cEMEG | 0.05U–0.5U | |
| Chromium [Hexavalent chromium] | 5/5 | 50 | cEMEG | 16.6–21.2 | |
| Cobalt | 5/5 | 500 | iEMEG | 3.0–26.3 | |
| Copper | 5/5 | 500 | iEMEG | 8.6–71.7 | |
| Iron | 5/5 | 55,000 | RSL | 9,730–15,900 | |
| Lead | 5/5 | 250 | MTCA | 8.9–30 | |
| Manganese | 5/5 | 2,500 | RMEG | 135–180 | |
| Mercury [Mercuric chloride] | 1/5 | 15 | RMEG | 0.021JQ –0.1 | |
| Nickel | 5/5 | 1,000 | RMEG | 21.4–52.6 | |
| Selenium | 0/5 | 250 | cEMEG | 0.41JQ –3.5U | |
| Silver | 0/5 | 250 | RMEG | 1.0U | |
| Thallium | 0/5 | 0.78 | RSL | 2.5U | 0 (5) |
| Vanadium | 5/5 | 500 | iEMEG | 21.6–36.5 | |
| Zinc | 5/5 | 15,000 | cEMEG | 23.2–79.9 | |
| Volatile Organic Compounds | | | | – | |
| Acetone | 1/5 | 45,000 | RMEG | 0.0066–0.028 | |
| Benzene | 1/25 | 13 | CREG | 0.0014–0.03 | |
| Ethylbenzene | 1/25 | 5,000 | RMEG | 0.0014–0.05 | |
| Methylene chloride | 19/25 | 300 | RMEG | 0.0013–1.0 | |
| Naphthalene | 1/25 | 1,000 | RMEG | 0.001–0.17 | |
| Trichloropropane, 1,2,3- | 0/25 | 0.023 | CREG | 0.0013–0.05 U | 0 (20) |
| Xylene, m- and p- | 1/25 | 10,000 | cEMEG**** | 0.0014–1.0 | |
| Total Petroleum Hydrocarbons | | | | | |
| Diesel range | 4/5 | 2,000 | MTCA | 25–245 | |
| Gasoline range | 0/5 | 2,000 | MTCA | 5–450 | |
| Heavy oil range | 5/5 | 2,000 | MTCA | 21–615 | |

**Source:** Anchor 2011 (1); E&E 2009 (2)

**Notes:**

[a] Bolded chemicals have detected concentrations in sediments that require further risk evaluation.

[b] Table includes detected chemicals and chemicals with detection limits above the CV. Compounds not detected not listed.

[c] ATSDR CVs based on child soil exposures were used for screening (CVs for sediment exposures have not been developed). To be conservative, soil CVs reflect residential exposures and are expected to overestimate sediment exposures on the shoreline.

[d] BaP CREG was used as a surrogate compounds chemicals that have no CV. BaP CREG was divided by potency factor relative (RPF) to BaP as presented by EPA 2010 (11) to obtain the CV.
[e] PAHs associated with carcinogenic effects (cPAHs). For each sample, each PAH is multiplied by potency factor relative (RPF) to BaP as presented by EPA 2010 (11). These are summed and presented as the Total cPAH BaP Equivalent (BaP-EQ).
[f] Per ATSDR, CV is health-based for non-carcinogenic effects only, not carcinogenic effects. CREG CV is below background.
* Acenaphthene was used as a surrogate
** Diphenylamine was used as a surrogate
*** Fluorene was used as a surrogate
**** Total Xylenes was used as a surrogate

**Table 2 Abbreviations:**

| | |
|---|---|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BaP | Benzo(a)pyrene |
| BaP-EQ | Benzo(a)pyrene equivalents |
| cEMEG | ATSDR Environmental Media Evaluation Guide based on chronic exposures (>365 days) based on MRL |
| cPAH | Polycyclic Aromatic Hydrocarbons that have carcinogenic adverse effects |
| CREG | ATSDR Cancer Risk Evaluation Guide |
| CV | Health-based comparison value (unless otherwise indicated) |
| EPA | U.S. Environmental Protection Agency |
| iEMEG | ATSDR Environmental Media Evaluation Guide based on intermediate exposures (90–365 days) based on MRL |
| mg/kg | milligrams of chemical per kilograms of sediment |
| MTCA | Washington State Model Toxics Control Act cleanup regulation |
| RMEG | ATSDR Reference Dose Media Evaluation Guide for non-carcinogenic adverse effects |
| RSL | EPA Regional Screening Level |
| U | Value undetected at the detection limit given |

**Table B2**. Chemical concentrations in **surface soil** samples (0–5 feet bgs) and health-based comparison values, Bremerton Gasworks Superfund site, Kitsap County, Washington.

| Chemical [a] | Number Detected / Total Sampled [b] | Soil CV [c] | Type of CV | Range of Concentrations (mg/kg) | Number Detected (and non-detected) greater than CV |
|---|---|---|---|---|---|
| Semivolatile Organic Compounds (mg/kg) | | | | | |
| **Benzo(a)anthracene** | 5/7 | 0.48 [d] | CREG/RPF | 0.48–1.6 | 2 |
| **Benzo(a)pyrene** | 5/7 | 0.096 | CREG | 0.57–2.5 | 2 |
| **Benzo(b)fluoranthene** | 5/7 | 0.12 [d] | CREG/RPF | 0.43–1.8 | 2 |
| **Benzo(k)fluoranthene** | 5/7 | 3.2 [d] | CREG/RPF | 0.0009 JQ– 2.2 | |
| **Benzo(g,h,i)perylene** | 5/7 | 10.7 [d] | CREG/RPF | 0.0011U– 2.4 | |
| **Chrysene** | 4/7 | 0.96 [d] | CREG/RPF | 0.52–3.9 | 2 |
| **Dibenzo(a,h)anthracene** | 5/7 | 0.0096 [d] | CREG/RPF | 0.78–1.1 U | 1(1) |
| **Fluoranthene** | 6/7 | 1.2 [d] | CREG/RPF | 0.0016U–12 J | 1 |
| **Indeno(1,2,3-cd)pyrene** | 5/7 | 1.4 [d] | CREG/RPF | 0.0013U –2.0 | 1 |
| **Total PAH BaP Equivalents** [f] | **6/7** | 0.096 [d] | BaP CREG | **0.3–13.6** [e] | **3** |
| Acenaphthene | 3/7 | 3,000 | RMEG | 0.0011U–1.1UJ | |
| Acenaphthylene | 3/7 | 3,000 | RMEG* | 0.0011U –2.4 | |
| Acetophenone | 1/7 | 5,000 | RMEG | 0.022U–1.8 | |
| Anthracene | 1/7 | 15,000 | RMEG | 0.0011U–1.1UJ | |
| Biphenyl, 1,1'- | 1/7 | 2,500 | RMEG | 0.022U–0.98 | |
| Carbazole | 2/7 | 1,300 | RMEG** | 0.023U–0.56 | |
| Dibenzofuran | 1/7 | 78 | RSL | 0.022U–0.063J | |
| Fluoranthene | 5/7 | 2,000 | RMEG | 0.0016–12J | |
| Fluorene | 3/7 | 2,000 | RMEG | 0.0011U–4.6 | |
| Methylnaphthalene, 2- | 3/7 | 200 | RMEG | 0.0011U–100 | |
| Naphthalene | 1/7 | 1,000 | RMEG | 0.0011U–270 | |
| Phenanthrene | 5/7 | 2,000 | RMEG*** | 0.0013U–40 | |
| Phthalate, Di(2-ethylhexyl) | 6/7 | 50 | CREG | 0.024UJ–0.24 | |
| Pyrene | 5/7 | 1,500 | RMEG | 0.0013U–12J | |
| Trimethylbenzene, 1,2,4- | 1/7 | 62 | RSL | 0.022U–2.6 | |
| Trimethylbenzene, 1,3,5- | 1/7 | 780 | RSL | 0.022U–5.5 | |
| **Metals (mg/kg)** | | | | | |
| Aluminum | 7/7 | 50,000 | cEMEG | 11,200J–24,100 | |
| Arsenic | 7/7 | 15 | cEMEG | 1.08–4.17 | |
| Barium | 7/7 | 10,000 | cEMEG | 46.1J–120 | |
| Cadmium | 2/7 | 5 | cEMEG | 0.27JQ–1.2 | |
| Chromium [Hexavalent chromium] | 7/7 | 50 | cEMEG | 28.1J–49.3 | |
| Cobalt | 7/7 | 500 | iEMEG | 5.8–14.8 | |

Table B2 (continued).

| Chemical [a] | Number Detected / Total Sampled [b] | Soil CV [c] | Type of CV | Range of Concentrations (mg/kg) | Number Detected (and non-detected) greater than CV |
|---|---|---|---|---|---|
| Copper | 7/7 | 500 | iEMEG | 11.1–45.7 | |
| Iron | 7/7 | 55,000 | RSL | 10,900J–28,500 | |
| Lead | 7/7 | 60 | IEUBK | 2.4J–31.2 | |
| Manganese | 7/7 | 2,500 | RMEG | 193J–526 | |
| Nickel | 7/7 | 1,000 | RMEG | 30.1J–65.7 | |
| **Thallium** | **4/7** | **0.78** | **RSL** | **2.2 JQ –4.1** | **2** |
| Vanadium | 7/7 | 500 | iEMEG | 26.5–62.6 | |
| Zinc | 7/7 | 15,000 | cEMEG | 23.6J–114 | |
| **Total Petroleum Hydrocarbons (mg/kg)** | | | | | |
| Diesel range | 1/7 | 2,000 | MTCA | 25U–1800 | |
| **Heavy oil range** | **3/7** | **2,000** | MTCA | 25U–**4,700J** | **1** |
| **Volatile Organic Compounds (ug/kg)** | | | | | |
| Acetone | 4/7 | 45,000 | RMEG | 0.0057U–1.2U | |
| Benzene | 2/7 | 13 | CREG | 0.0011U –4.8 | |
| Ethylbenzene | 2/7 | 5,000 | RMEG | 0.0011U –3.6 | |
| Isopropylbenzene cumene | 2/7 | 5,000 | RMEG | 0.0011U –0.13 | |
| Tetrachloroethylene | 1/7 | 300 | RMEG | 0.001U –0.58U | |
| Toluene | 3/7 | 4,000 | RMEG | 0.0011U –7.7 | |
| Trichlorobenzene, 1,2,3- | 0/7 | 500 | RMEG**** | 0.0013U –0.58U | |
| Trichlorobenzene, 1,2,4- | 0/7 | 500 | RMEG | 0.001U –0.58U | |
| Trichlorofluoromethane | 0/7 | 15,000 | RMEG | 0.001U –0.58U | |
| Xylene, o- | 2/7 | 10,000 | cEMEG***** | 0.001U –3.4 | |

**Source:** E&E 2009 (2)

**Notes:**

[a] Bolded chemicals have detected concentrations in surface soil that people could come in contact with. Further evaluation is not done in this report until more information on extent and future land use is available.

[b] Chemicals analyzed but not detected are not listed. However, table includes chemicals with detection limits above the CV.

[c] ATSDR CVs based on child residential soil exposures.

[d] BaP CREG was used as a surrogate compounds chemicals that have no CV. BaP CREG was divided by potency factor relative (RPF) to BaP as presented by EPA 2010 (11) to obtain the CV.

[e] PAHs associated with carcinogenic effects (cPAHs). For each sample, each PAH is multiplied by potency factor relative (RPF) to BaP as presented by EPA 2010 (11). These are summed and presented as the Total cPAH BaP Equivalent (BaP-EQ).

[f] Per ATSDR, CV is health-based for non-carcinogenic effects only, not carcinogenic effects. CREG CV is below background.

* Acenaphthene was used as a surrogate

** Diphenylamine was used as a surrogate

*** Fluorene was used as a surrogate

**** Trichlorobenzene, 1,2,4- was used as a surrogate

***** Total Xylenes was used as a surrogate

**Abbreviations:**

| | |
|---|---|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BaP-EQ | Benzo(a)pyrene equivalents |
| cEMEG | ATSDR Environmental Media Evaluation Guide based on chronic exposures (>365 days) based on MRL |
| cPAH | Polycyclic Aromatic Hydrocarbons that have carcinogenic adverse effects |
| CREG | ATSDR Cancer Risk Evaluation Guide |
| CV | Health-based comparison value (unless otherwise indicated) |

| | |
|---|---|
| EPA | U.S. Environmental Protection Agency |
| iEMEG | ATSDR Environmental Media Evaluation Guide based on intermediate exposures (90–365 days) based on MRL |
| J | Chemical positively identified but outside of quality control limits and considered an estimate |
| JQ | Chemical detected below the reporting limit but above the detection limit and considered an estimate |
| mg/kg | milligrams of chemical per kilograms of sediment |
| MTCA | Washington State Model Toxics Control Act cleanup regulation |
| RMEG | ATSDR Reference Dose Media Evaluation Guide for non-carcinogenic adverse effects |
| RSL | EPA Regional Screening Level |
| U | Value undetected at the detection limit given |
| UJ | Chemical was not detected at or above the reporting value. The associated value is an estimate. |
| ug/kg | micrograms of chemical per kilograms of soil |
| bgs | Below ground surface |

Table B3. Chemical concentrations in **groundwater** samples and health-based drinking water comparison values, Bremerton Gasworks Superfund site, Kitsap County, Washington.

| Chemical [a] | Number Detected / Total Sampled [b] | Drinking Water CV (µg/L) [c] | Type of CV | Range of Concentrations (µg/L) | Number Detected (and Non-detected) greater than CV |
|---|---|---|---|---|---|
| **Semivolatile Organic Compounds** | | | | | |
| **Benz(a)anthracene** | 4/5 | 0.024 [d] | CREG/RPF | 0.05 U–0.66 | **2** |
| **Benzo(a)pyrene (BaP)** | 2/5 | 0.0048 | CREG | 0.05 U–1.1 | **2** |
| **Benzo(b)fluoranthene** | 2/5 | 0.006 [d] | CREG/RPF | 0.05 U–0.59 | **2** |
| **Benzo(k)fluoranthene** | 3/5 | 0.16 [d] | CREG/RPF | 0.7 | **1** |
| **Benzo(g,h,i)perylene** | 2/5 | 0.53 [d] | CREG/RPF | 0.12–0.82 | **2** |
| **Chrysene** | 3/5 | 0.048 [d] | CREG/RPF | 0.068–1.1 | **2** |
| **Dibenz(a,h)anthracene** | 1/5 | 0.00048 [d] | CREG/RPF | 0.05U–0.5U | **1** |
| **Fluoranthene** | 4/5 | 0.060 [d] | CREG/RPF | 0.12–3.7 | **4** |
| **Indeno(1,2,3-cd)pyrene** | 2/5 | 0.069 [d] | CREG/RPF | 0.090–0.40 | **2** |
| **Total PAH B(a)P Equivalent [f]** | **4/5** | 0.0048 [d] | CREG | **0.61U–3.0** [e] | **4** |
| Acenaphthene | 2/5 | 600 | RMEG | 0.05U–38 | |
| Acenaphthylene | 3/5 | 600 | RMEG* | 0.05U–5.4J | |
| Acetophenone | 1/5 | 1,000 | RMEG | 0.5U–3.8 | |
| Anthracene | 4/5 | 3,000 | RMEG | 0.05U–2.9 | |
| Biphenyl, 1,1'- | 1/5 | 500 | RMEG | 0.5U–6.3 | |
| Caprolactam | 1/5 | 5,000 | RMEG | 0.48JQ–6.3J | |
| Carbazole | 2/5 | 400 | RMEG** | 0.5U–24 | |
| Dibenzofuran | 1/5 | 6 | RSL | 0.29JQ–1.1 | |
| Dimethylphenol, 2,4- | 1/5 | 200 | RMEG | 0.5U–32 | |
| Fluoranthene | 4/5 | 400 | RMEG | 0.05U–3.7 | |
| Fluorene | 3/5 | 400 | RMEG | 0.05U–6.1 | |
| **Methylnaphthalene, 2-** | **5/5** | **40** | **RMEG** | 0.11–**170J** | **1** |
| Methylphenol, 4- | 1/5 | 500 | RMEG*** | 0.5U–2.3 | |
| Phenanthrene | 2/5 | 400 | RMEG** | 0.05U–6.7 | |
| Phenol | 1/5 | 3,000 | RMEG | 0.05U –33 | |
| Phthalate, Di(2-ethylhexyl) | 2/5 | 2.5 | CREG | 0.33JQ–0.78 | |
| Phthalate, Diethyl | 0/5 | 8,000 | RMEG | 0.34JQ–0.5U | |
| Phthalate, Butyl benzyl | 1/5 | 2,000 | RMEG | 0.33JQ–1 | |
| Pyrene | 4/5 | 300 | RMEG | 0.05U–1.6 | |
| **Trimethylbenzene, 1,2,4-** | **1/5** | **15** | **RSL** | 0.5U–**16** | **1** |
| **Trimethylbenzene, 1,3,5-** | **1/5** | **87** | **RSL** | 0.5U–**98** | **1** |
| Metals (ug/L) | | | | | |
| Antimony | 6/8 | 4 | RMEG | 0.16–2.0 | |
| **Arsenic** | **8/8** | **0.023** | **CREG** | **0.04–4.1** | **5** |

Table B3 (continued).

| Chemical [a] | Number Detected / Total Sampled [b] | Drinking Water CV (µg/L) [c] | Type of CV | Range of Concentrations (µg/L) | Number Detected (and Non-detected) greater than CV |
|---|---|---|---|---|---|
| Barium | 8/8 | 2,000 | cEMEG | 0.10–3,140 | **2** |
| Beryllium | 4/8 | 4 | MCL | 0.37–**7.6** | **2** |
| Cadmium | 5/8 | 1 | cEMEG | 0.16–**3.9** | **4** |
| Chromium [hexavalent chromium] | 8/8 | 9 | cEMEG | 0.05–**1,670** | **4** |
| Cobalt | 5/5 | 100 | iEMEG | 1.4 – 44.8 | |
| Copper | 1/7 | 100 | iEMEG | 0.16–111 | **1** |
| Lead | 5/8 | 15 | MCL | 1.0 U–**268** | **3** |
| Manganese | 8/8 | 500 | RMEG | 0.32–**25,600** | **4** |
| Nickel | 8/8 | 200 | RMEG | 0.1- 125 | |
| Selenium | 8/8 | 50 | cEMEG | 1.4 – 5.5 | |
| Silver | 8/8 | 50 | RMEG | 0.07 – 1.4 | |
| Thallium | 4/8 | 2 | MCL | 0.26 – 1.0 | |
| Vanadium | 5/8 | 100 | iEMEG | 3.7 JQ–**717** | **3** |
| Zinc | 7/8 | 3,000 | cEMEG | 0.9 - 153 | |
| **Total Petroleum Hydrocarbons** | | | | | |
| **Diesel range** | **5/6** | **500** | **MTCA** | **510–5,500** | **2** |
| **Volatile Organic Compounds** | | | | | |
| Acetone | 0/6 | 9,000 | RMEG | 3.9JQ–500UJ | |
| **Benzene** | **3/6** | **0.64** | **CREG** | 0.25U–**3,100J** | **3** |
| Cyclohexane | 1/6 | 13,000 | RSL | 0.25U–0.38 | |
| Ethylbenzene | 1/6 | 700 | MCL | 0.25U–190JQ | |
| Isopropyl benzene (cumene) | 1/6 | 1,000 | RMEG | 0.25U–22JQ | |
| **Naphthalene** | **3/6** | **100** | **LTHA** | 0.25UJ –**1,800** | **1** |
| Toluene | 2/6 | 800 | RMEG | 0.25U–58J | |
| **Trichloroethene** | **2/6** | **0.76** | **CREG** | 0.25U–**25 UJ** | **0 (1)** |
| Xylene, o- | 2/6 | 2000**** | cEMEG | 0.25U–640J | |

**Source: Anchor 2011 (1); E&E 2009 (2)**

**Notes:**

[a] Bolded chemicals have detected concentrations that exceeded CV.

[b] Chemicals analyzed but not detected are not listed. However, table includes chemicals with detection limits above the CV.

[c] ATSDR CVs based on child residential soil exposures.

[d] BaP CREG was used as a surrogate compounds chemicals that have no CV. BaP CREG was divided by potency factor relative (RPF) to BaP as presented by EPA 2010 (11) to obtain the CV.

[e] PAHs associated with carcinogenic effects (cPAHs). For each sample, each PAH is multiplied by potency factor relative (RPF) to BaP as presented by EPA 2010 (11). These are summed and presented as the Total cPAH BaP Equivalent (BaP-EQ).

[f] Per ATSDR, CV is health-based for non-carcinogenic effects only, not carcinogenic effects. CREG CV is below background.

* Acenaphthene was used as a surrogate

** Fluorene was used as a surrogate

*** cresol, m was used as a surrogate

**** Total Xylenes was used as a surrogate

**Abbreviations:**

ATSDR Agency for Toxic Substances and Disease Registry

BaP-EQ Benzo(a)pyrene equivalents

cEMEG ATSDR Environmental Media Evaluation Guide based on chronic exposures (>365 days) based on MRL

| | |
|---|---|
| cPAH | Polycyclic Aromatic Hydrocarbons that have carcinogenic adverse effects |
| CREG | ATSDR Cancer Risk Evaluation Guide |
| CV | Health-based comparison value (unless otherwise indicated) |
| EPA | U.S. Environmental Protection Agency |
| iEMEG | ATSDR Environmental Media Evaluation Guide based on intermediate exposures (90–365 days) based on MRL |
| RMEG | ATSDR Reference Dose Media Evaluation Guide for non-carcinogenic adverse effects |
| LTHA | EPA Lifetime Health Advisory for drinking water |
| RSL | EPA Regional Screening Level |
| U | Value undetected at the detection limit given |
| UJ | Chemical was not detected at or above the reporting value. The associated value is an estimate. |
| J | Chemical positively identified but outside of quality control limits and considered an estimate |
| JQ | Chemical detected below the reporting limit but above the detection limit and considered an estimate |
| PAH | Polycyclic Aromatic Hydrocarbons |
| µg/L | micrograms of chemical per liter of water |

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# Appendix C–Exposure and Risk Methodology and Assumptions

This appendix of the public health assessment (for initial/public comment release) for the Bremerton Gasworks Superfund Site provides the methodology and assumptions (Table C1) used to calculate exposure doses for people coming into contact with the intertidal sediment at the site. A summary of exposure doses and health risk calculations are summarized for carcinogenic risks (Table C2).

The following scenarios for sediment exposures have been defined for this site:

- Future hypothetical resident (adult and child) playing at the beach daily.
- Visitor (adult and child) during the summer months (or frequency of 1–2 times per year).
- Trespasser (adult) on the sediments 3 days a week.

## Data Compilation

For chemicals with samples detected below the reporting limit but above the detection limit, the estimated value was used. Estimated values were designated by a "J" flag. Compounds that were not detected (designated with a U flag) were assumed to be present at the detection limit.

When possible, exposure point concentrations for sediments were derived by using a conservative estimate of the mean concentration. This conservative estimate is typically the upper limit of a 95% confidence interval (95% UCL) of the average concentration. The 95% UCL was calculated by ProUCL 4.1.00[8] (16). The method of calculation was based on sample size, coefficient of variation, and the underlying distribution of the data. The sediment sampling source, location, number, and analytical data are listed in Appendix C and Table 2 in the main text.

At this time, there are not sufficient soil, air, fish and shellfish tissue or blackberry data to estimate potential exposures. After these data gaps have been filled, these pathways can also be evaluated. All intertidal sediment samples from the Brownfield Assessment (2) and the emergency interim action (1) were combined together to calculate the sediment exposure point concentration ($C_s$) for incidental ingestion and dermal contact at the beach. The data from the Ecology investigation in 1995 were not used as they are 15 years old.

It is important to point out that although residents have unrestricted access to the shoreline at this time, tidal fluctuations prevent access to sediments and decrease exposure frequency. Low tides permitting access to the shoreline during the day[9] occur about 60% of the year (218 out of 365 days) mostly between March and September. DOH assumed that a resident nearby could be exposed a maximum number of 218 days and likely will be exposed much less frequently.

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[8] http://www.epa.gov/osp/hstl/tsc/software.htm

[9] Estimated number of days with low tides permitting access to the shoreline during the day were assumed to occur between 7 a.m. and 7 p.m., includes +4 tides or less relative to the average of the lowest tides recorded at this tide station (mean lower low water), and are based on NOAA 2011 data from the Tracyton, Dyes Inlet, tide station.

## Sediment Exposure Cancer Dose Calculations

This section provides the assumptions and calculations used to estimate daily intakes for exposure to chemicals in sediments at the site. Cancer exposure doses were calculated for incidental ingestion of sediment and dermal absorption of sediment adhered to skin. Inhalation of sediment particles was not considered as a route of exposure since inhalation of dust particles from wet sediments are not expected to occur. Volatile and semi-volatile organic chemicals in sediments have been identified as contaminants of concern.

The following equations were used to calculate cancer exposures doses and risks:

**Equation C1: Incidental Ingestion Route**

$$Cancer\ Dose_{ing} = \frac{C_s \times IR \times EF \times CF}{BW} \text{ Where, } EF = \frac{F \times ED}{AT}$$

The exposure factor (EF) will vary depending on the scenario (see scenario-specific calculations for EF in Table C1).

**Equation C2: Skin Contact Route**

$$Cancer\ Dose_{der} = \frac{C_s \times AF \times ABS \times AD \times CF \times SA \times EF}{BW} \text{ Where, } EF = \frac{F \times ED}{AT}$$

Again, the exposure factor (EF) will vary depending on the scenario (see scenario-specific calculations for EF in Table C1).

**Equation C3: Carcinogenic mutagenic risks (CMR) or (Carcinogenic risks)**

$$CMR = Cancer\ Dose \times CSF \times ADAF$$

If the carcinogenic risks are greater than an increased incidence of 1 cancer per 1,000,000 people ($1 \times 10^{-6}$), the exposure dose is discussed further in the text.

**Table C1**. Exposure assumptions used in exposure evaluation of people in contact with sediments at the former MGP in Bremerton, Washington.

| Parameter and Abbreviation | | Value | Units | Source |
|---|---|---|---|---|
| Cancer exposure dose for ingestion route | D(ing) | Calc. | mg/kg-day | D(ing) = C*IR*CF*EF/BW |
| Cancer exposure dose for dermal route | D(der) | Calc. | mg/kg-day | D(der) = (C*AF*ABS*AD*CF*EF*SA)/BW |
| Concentration in sediment | $C_s$ | Calc. | mg/kg | Mean chemical-specific concentration for sediment (95% UCL of the mean if adequate data available) |
| Conversion factor | CF | 0.000001 | kg/mg | Converts from kilograms soil to milligrams soil |
| Age-specific body weight | BW | 9.2 | kg | Body weight, Child 0.5 to < 1 year (EFH) |
| | | 11.4 | | Body weight, Child 1 to < 2 years (EFH) |
| | | 17.4 | | Body weight, Child 2 to < 6 years (EFH) |
| | | 31.8 | | Body weight, Child 6 to < 11 years (EFH) |
| | | 56.8 | | Body weight, Child 11 to < 16 years (EFH) |
| | | 71.6 | | Body weight, Child 16 to < 21 years (EFH) |
| | | 80 | | Body weight, Adult 21 to < 65 years (EFH) |
| | | 76 | | Body weight, Adult 65+ years (EFH) |
| Exposure factor (EF=F*ED/AT) | EF | Variable | unitless | Local resident (daily exposure at low tide) |
| | | | | Visitor |
| | | | | Trespasser |
| Frequency | F | 218 | days/year | Resident: low tides occur during the day for 60% of the year (218/365 based on NOAA 2011 data) |
| | | ~90 | | Visitor: summertime months (3 months a year) |
| | | 156 | | Trespasser: onsite 3 days a week |
| Age-specific exposure duration | ED | 0.5 | year | Child 0.5 to < 1 year |
| | | 1 | | Child 1 to < 2 years |
| | | 4 | | Child 2 to < 6 years |
| | | 5 | | Child 6 to < 11 years |
| | | 5 | | Child 11 to <16 years |
| | | 5 | | Child 16 to <21 years |
| | | 44 | | Adult 21 to < 65 years |
| | | 14 | | Adult 65+ |
| Averaging time | AT | 28470 | day | Tribal averaging time, number of days in lifetime (78 years*365 days per year) |
| Age-dependent adjustment factor for mutagenicity | ADAF | 10 | unitless | Children < 2 years |
| | | 3 | | Children 2 to < 16 years |
| | | 1 | | Young adults and adults 16 years and older |
| Cancer risk | CMR | Calc. | $(mg/kg\text{-}day)^{-1}$ | Increased risk of getting cancer CMR=D*CSF*ADAF |
| Cancer slope factor | CSF | 7.3 | unitless | For BaP used as a reference chemical for cPAHs, published by EPA |

Table C1 (continued).

| Parameter and Abbreviation | | Value | Units | Source |
|---|---|---|---|---|
| Ingestion Parameters | | | | |
| Incidental ingestion rate (central tendency) | IR | 60 | mg/day | Child 0.5 to < 1 year |
| | | 100 | | Child 1 to < 21 years |
| | | 50 | | Adult |
| Dermal Parameters | | | | |
| Absorption duration | AD | 1 | day | Fraction of day sediment is in contact with the skin (worst-case) RAGS E |
| Skin-sediment adherence factor | AF | 0.2 | $mg/cm^2$ | Amount of sediment that adheres to skin, child 1-6 years (RAGS E) |
| | | 0.07 | | Amount of sediment that adheres to skin, child and adult (7-31 years) (RAGS E) |
| Dermal absorption factor | ABS | PAH 0.13 | unitless | Chemical-specific, fraction of chemical that absorbs through the skin in 24-hours (EPA RSL; EPA RAGS E) |
| Surface area | SA | 2900 | $cm^2$ | Surface area exposed, child 1-6 years (RAGS E) |
| | | 5700 | | Surface area exposed, child and adult 7-31 years (RAGS E) |

Sources: Guidance for developing soil screening levels for Superfund sites Abbreviations not defined in the table:

BaP Benzo(a)Pyrene used as the reference compound for PAHs with carcinogenic effects (cPAH)
Calc. Calculated
cm centimeters
EFH EPA Exposure Factors Handbook 2011
EPA U.S. Environmental Protection Agency
mg milligram
NOAA National Oceanic Atmospheric Administration
kg kilogram
cPAH polycyclic aromatic hydrocarbons with carcinogenic effects
RAGS E EPA Risk Assessment Guidance for Superfund Part E, Volume 1: Human Health Evaluation Manual (Part E - Supplemental Guidance for Dermal Risk Assessment)
RSL EPA Regional Screening Levels
UCL upper confidence limit of the mean

## Results

**Table C2.** Estimated cancer risks resulting from central tendency exposures to carcinogenic polycyclic aromatic hydrocarbons (cPAH)[a] in intertidal sediments near the former MGP from Bremerton, Kitsap County, Washington.

| Exposure Pathway | Age | Concentration (mg/kg) [b] | Estimated Cancer Dose | | | Cancer Slope Factor | ADAF | Increased Cancer Risk | | | Age [c] | Total Cancer Risk |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Incidental Ingestion | Dermal Contact | Total Dose | | | Incidental Ingestion | Dermal Contact | Total Cancer Risk | | |
| Resident (daily during low tides) | Child 0.5 to < 1 year | 159 | 3.97E-6 | 4.99E-6 | 8.96E-6 | 7.3[a] | 10 | 2.90E-4 | 3.64E-4 | 6.54E-4 | Young Child | 3.1E-03 |
| | Child 1 to < 2 years | | 1.07E-5 | 8.05E-6 | 1.87E-5 | | 10 | 7.80E-4 | 5.88E-4 | 1.37E-3 | | |
| | Child 2 to < 6 years | | 2.80E-5 | 2.11E-5 | 4.91E-5 | | 3 | 6.13E-4 | 4.62E-4 | 1.08E-3 | | |
| | Child 6 to < 11 years | | 1.91E-5 | 2.84E-5 | 4.75E-5 | | 3 | 4.19E-4 | 6.21E-4 | 1.04E-3 | Older Child | 1.4E-03 |
| | Child 11 to <16 years | | 1.07E-5 | 1.59E-5 | 2.66E-5 | | 3 | 2.35E-4 | 1.26E-4 | 3.61E-4 | | |
| | Child 16 to <21 years | | 8.50E-6 | 1.26E-5 | 2.11E-5 | | 1 | 6.21E-5 | 3.33E-5 | 9.54E-5 | Young Adult to Adult | 7.6E-04 |
| | Adult 21 to < 65 years | | 3.35E-5 | 3.47E-5 | 6.82E-5 | | 1 | 2.44E-4 | 2.54E-4 | 4.98E-4 | | |
| | Adult 65+ | | 1.12E-5 | 1.16E-5 | 2.28E-5 | | 1 | 8.19E-5 | 8.49E-5 | 1.67E-4 | | |
| | **Lifetime** | | **1.26E-4** | **1.37E-4** | **2.63E-4** | | | **2.72E-03** | **2.35E-03** | **5.26E-3** | | **5.26E-3** |
| Visitor (daily during summertime only) | Child 0.5 to < 1 year | 159 | 1.64E-6 | 2.06E-6 | 3.70E-6 | | 10 | 1.20E-4 | 1.50E-4 | 2.70E-4 | Young Child | 1.28E-03 |
| | Child 1 to < 2 years | | 4.41E-6 | 3.32E-6 | 7.73E-6 | | 10 | 3.22E-4 | 2.43E-4 | 5.65E-4 | | |
| | Child 2 to < 6 years | | 1.16E-5 | 8.71E-6 | 2.03E-5 | | 3 | 2.53E-4 | 1.91E-4 | 4.44E-4 | | |
| | Child 6 to < 11 years | | 7.90E-6 | 1.17E-5 | 1.96E-5 | | 3 | 1.73E-4 | 2.57E-4 | 4.30E-4 | Older Child | 5.79E-04 |
| | Child 11 to <16 years | | 4.42E-6 | 6.56E-6 | 1.10E-5 | | 3 | 9.69E-5 | 5.20E-5 | 1.49E-4 | | |
| | Child 16 to <21 years | | 3.51E-6 | 5.20E-6 | 8.71E-6 | | 1 | 2.56E-5 | 1.38E-5 | 3.94E-5 | Young Adult to Adult | 3.14E-04 |
| | Adult 21 to < 65 years | | 1.38E-5 | 1.43E-5 | 2.82E-5 | | 1 | 1.01E-4 | 1.05E-4 | 2.06E-4 | | |
| | Adult 65+ | | 4.63E-6 | 4.80E-6 | 9.43E-6 | | 1 | 3.38E-5 | 3.51E-5 | 6.89E-5 | | |
| | **Lifetime** | | **5.19E-5** | **5.67E-5** | **1.09E-4** | | | **1.12E-03** | **1.05E-03** | **2.17E-3** | | **2.17E-3** |
| Trespasser (3 days per week) | Child 16 to <21 years | 159 | 6.08E-6 | 9.02E-6 | 1.51E-5 | | 1 | 4.44E-5 | 2.38E-5 | 6.83E-5 | Young Adult to Adult | 5.44E-04 |
| | Adult 21 to < 65 years | | 2.40E-5 | 2.49E-5 | 4.88E-5 | | 1 | 1.75E-4 | 1.81E-4 | 3.56E-4 | | |
| | Adult 65+ | | 8.02E-6 | 8.32E-6 | 1.63E-5 | | 1 | 5.86E-5 | 6.08E-5 | 1.19E-4 | | |

Notes:
a – Carcinogenic polycyclic aromatic hydrocarbons (cPAHs) classified by EPA as Group B2 Probable Human Carcinogens; calculations performed with EPA's slope factor 7.3 $(mg/kg\text{-}day)^{-1}$. Concentrations of each PAHs multiplied by carcinogenic potency factors relative to Benzo(a)pyrene (BaP) according to EPA 2010 and summed/expressed as BaP equivalents (BEQ).
b – Concentration represents 95% upper confidence limit of the mean sediment samples
c – Age groupings are young (0.5 to < 6 years), older (6 to < 16 years old) and young adult/adult (16 years and older)
Abbreviations: EPA – Environmental Protection Agency; mg/kg – milligrams chemical per kilogram sediment
ADAF - Age-dependent adjustment factor for mutagenicity
$(mg/kg\text{-}day)^{-1}$ – milligrams per kilograms per day

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